TDT4290 - Customer Driven Project

Norwegian Public Road Administration

Datarec Error Monitoring and Notification

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Abstract

The Norwegian Public Road Administration (NPRA) is the public agency responsible for the public road network and security in Norway. They have numerous road-side installations that perform vehicle counting and statistics. These road-side installations stores data that can be accessed through various interfaces. Currently the NPRA has a manual and labour-intensive method of collecting and processing this data. As it is now, it can take up to several months before the information gathered can be of any use. This is due to the fact that the road-side installations do not notify anyone of hardware errors, forcing the NPRA to manually check if the data is usable.

The NPRA has asked for a proof-of-concept system that automatically detects and stores hardware errors that may corrupt the statistics gathered by the road-side installations. Through the course *TDT4290 - Customer Driven Project*, they have asked student group 10 to create this solution. This meant that we would take on the role of consultants, and the NPRA would be the customer.

This report is the documentation of the development process. It describes the process from preliminary study and planning through implementation to the project evaluation. The report consists of chapters describing these phases in detail, given in an intuitive order.

To solve the problem we developed a SOAP based service that continuously requests the status of the installations and pushes any changes to an error handler. This service was to be placed on a computer connected to the road-side equipment. The error handler checks the received statuses for errors or irregularities and stores them in a database. In addition to this, a web service and a web page was created. The web service acts as the access point to the information stored in the database, and the web page shows the statuses of the road-side equipment in a list, and the errors are shown on a map with a location marker.

For a future system, we recommend using a push-based protocol. Even though it is more complex than a pull-based protocol, it will make the system real-time at minimum bandwidth costs by only pushing when there are any changes. The Datex II v2.0 standard seems to be a good choice as it aims at traffic management and road-side data gathering, and supports both pushing and pulling of data.

As for further use of the traffic data, we suggest, among other things, making it available for emergency transport, helping them calculate the most efficient route to their destination.

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Acronyms and Glossary

API Application Programming Interface - An interface for third party applications, so that it's possible to communicate between software.

COTS Commercial of-the-shelf.

DB Database.

Error An error is when the internal state of the system deviates from the correct service state. [3]

Failure The inability of the Datarec 7 hardware to perform its required functions. [3]

Faraday cage An enclosure formed by conducting material that blocks out external static and non-static electric fields. [32]

Fault A fault is a defect in a hardware device or component, or an incorrect step, process, or data definition in a computer program. [3]

Gantt Chart A bar chart used for demonstrating project schedules.

HTML Hypertext Markup Language - A standard language for web pages.

HTTP Hypertext Transfer Protocol - A communication protocol that is used for data transfer between a server and a client.

HTTPS Hypertext Transfer Protocol Secure - A communication protocol used for encrypted data transfer of web pages.

IDE Integrated Development Environment.

ISO International Organization of Standardization.

JAVA EE JAVA Enterprise Edition.

JAVA RMI JAVA Remote Method Invocation.

JDBC JAVA Database Connectivity.

JMS JAVA Message Service.

JSP JAVA Server Pages.

JVM JAVA Virtual Machine.

MIB Management Information Base.

NPRA Norwegian Public Roads Administration (Statens Vegvesen)

PHP PHP, Hypertext Preprocessor.

PMA Post Mortem Analysis - A method used to evaluate a project to find weak and strong points in the project.

RMON Remote Monitoring - A standard monitoring specification.

SDK Software Development Kit - A set of development tools that help in the creation of applications.

SNMP Simple Network Management Protocol.

SVN Subversion.

SQL Structured Query Language.

URL Uniform Resource Locator.

XML Extensible Markup Language - A universal and extensible markup language.

Preface

This project report, together with the proof-of-concept prototype, is the deliverable in the course Customer Driven Project, TDT4290. This course is a subject at the Norwegian University of Science and Technology, NTNU.

We got an assignment from the Norwegian Public Roads Administration (Statens Vegvesen). The assignment was to create a system that could report errors in real time for their existing roadside equipment. This system had to be a web application that can easily be integrated into their existing system.

We would like to thank our supervisor, Reidar Conradi, for his continuous feedback during the project.

We would also like to thank the customer representatives, Jo Skjermo and Kristin Gryteselv, from the Norwegian Public Roads Administration, for making this possible.

Trondheim, November 23, 2011

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Sonik Shrestha

Part I Introduction

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This section will present the purpose of the project, the mandate and the goal.

1.1 Project Name

The title of the project is "Hardware fault monitoring and notification for roadside infrastructure". It was given by the customer, and it describes in short what will be created. For more information about the problem and solutions, see Preliminary Study, section 3.

1.2 Original Project Description

> "The Norwegian Public Roads Administration has a large number of installations at the side of the Norwegian road network that performs vehicle registration and counting. The data from these installations is used for multiple purposes, included deciding on future infrastructure needs.
>
> As of today there is no overall system for detection or notification of hardware failure at these installations, even if the hardware is able to perform some self-diagnostic. Because of this the collected data has to undergo a manual and somewhat labor-intensive process before it can be of further use. With better notification and logging of errors this process can hopefully be reduced.
>
> Our wish is a design and prototype for a system that gather information on both hardware (Datarec7 or newer) and data communication state (given from our telecom provider), and display this information in a clear interface. We wish for a web-based interface where we can check status, analyze faults and read out state logs. We also wish to examine if it is possible to automatically estimate undetected hardware errors from lack of expected vehicle traffic, and

> display this in the interface. Automatic notification of hardware faults to the correct instances using sms or email could also be considered. Finally, it is also a wish that the system should be easy to integrate into existing systems and databases at the Norwegian Public Roads Administration." [8]

In the original project description the words error, fault and failure are used to denote the same threat. We have chosen to use different meanings for each word. Their respective meaning is defined in the glossary.

1.3 Project Goal

For this project the ultimate goal was to deliver a well defined and functional prototype product which related to the client's expectations. This report summarizes the handling and work done and assures that the customer can continue to work on the prototype delivered and integrate it into the existing system.

We agreed to strive for the best grade possible, and as such it was a major driver in reaching the project goal.

During the project phase there were plenty of things to learn. Beforehand, we had expectations to acquire a sense of real life work experience. Other big goals would be to learn as much as possible about working in teams, documenting a customer project process, and learning as much as possible about the technical aspects involved in the development of the software.

In the customer's current systems, the Datarec 7 hardware has no good way of notifying maintenance crew about errors. This leads to a high percentage of downtime when the hardware is of no use. This downtime also lead to loads of extra work, since the information has to be controlled before it can be used. Our practical goal of the project is to develop a prototype system for the customer that will drastically lower this percentage of downtime, by making the Datarec 7 hardware automatically notify maintenance crew about errors if they occur.

When the NPRA gather the data that is collected by the Datarecs, they can very rarely use a 100% of it. If they download the data directly from the site, 85-95% of the data are on average usable. If downloaded form the Traffic6 software though, the percentage of usable data can go as low as 50%. This is a worryingly low number. Hopefully the proof-of-concept system that we are developing will improve this number drastically.

1.4 Involved Parties

There are three groups of stakeholders for this project. The customer, the Customer Driven Project course staff and the project group.

The customer is represented through:

- Jo Skjermo
- Kristin Gryteselv

The course staff, represented through:

- Reidar Conradi

The project group:

- Kato Stølen
- Roar Bjurstrøm
- Bjørnar Valle
- Sondre Løberg Sæter
- Eirik Stene
- Robert Versvik
- Sonik Shrestha

1.5 The Customer

The customer that represented the assignment is The Norwegian Public Roads Administration, a Norwegian government agency. Being one of the largest agencies in Norway, they are responsible for the planning, construction and operation of the national road network, vehicle inspection and vehicle requirements, driver training and licensing. Before the founding of The Norwegian Public Roads Administration, Justisdepartementet had the responsibility of public roads in Norway. [16]

In 1864, The Directorate of Public Roads were established and Norway got their first 'Vegdirektør'. From 1885 to 1944 it was placed under The Ministry of Labour, and has since been a subordinate of The Ministry of Transport.

Jo Skjermo and Kristin Gryteselv represent the Intelligent Transport System and Services (ITS) department of The Norwegian Public Roads Administration. ITS is a common

term for the use of information and communication technology in the transport sector. Through the use of technology, the ITS department is trying to make a safer transportation system with better passability, accessibility and a better environment. [25]

1.6 Project Background

The Norwegian Public Roads Administration are recording the individual vehicles that pass certain points on the public roads. To do this, they have installed roadside equipment throughout Norway. Their solution, as of today, records the number of vehicles, as well as the velocity and the length of the vehicle. The system does not have the ability to report errors on this equipment. Therefore, the customer came to us with the task to create a system that runs diagnostics on the system. The system should have the ability to send notifications if any errors occur. This information should be displayed through a web service.

The web service shows different kinds of error messages. It reports whether there is a failure, what type of failure it is, what kind of equipment it is and where it is located.

1.7 Duration

The estimated workload per person was 5 hours each day. This gives 25 hours per person every week in the assigned project period. During the semester, this adds up to 310 hours for each project member. Since our group consisted of seven students, the estimated workload would be 2170 hours for the whole project.

Project Start: 30th of August, 2011.
Project end and presentation: 24th of November, 2011.

2 Planning

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This section is dedicated to the planning of the project. It describes the organization, scheduling and risk management of the project.

2.1 Phases

To get a better overview of the project, we divided the process into phases. The first two phases are spent on planning and preliminary study, while the remaining phase is an implementation phase. The planning of this phase is covered in section 5.1. A report phase for evaluation was also added, since writing the report is a continuous process throughout the project and consumes a lot of time. The phases are shown in the Gantt chart below.

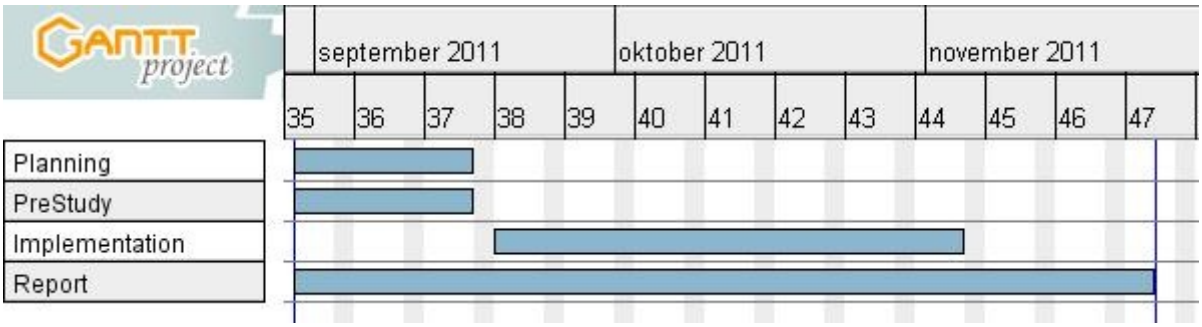

Figure 2.1: Gantt-Chart Diagram

2.1.1 Planning Phase

Organizing the process is an essential part of the project. A thorough plan will help us to get off to a good start and keep up the momentum. It is also important to identify risks and create strategies to avoid or minimize the impact of them.

2.1.2 Preliminary Study

The preliminary study phase is dedicated to getting a good understanding of the problem at hand, and identifying the existing solutions. By getting a good overview of both the problem and the solution space, the probability of making a satisfiable system increases significantly. The result of the preliminary study will be a choice of life cycle model and a prioritized list of requirements.

2.1.3 Implementation

The implementation phase of our project is the part where the implementation of the system is carried out. The choice of how to execute this phase is based on the conclusion of the preliminary study.

2.1.4 Report Writing

Writing the report, meeting summaries and agendas consumes a lot of time, and for this reason a report phase was created. This phase runs in parallel with the other phases and stretches from the beginning to the end of the project.

2.1.5 Effort Estimation and Registration

In order to keep record of the progress, a system that shows the actual hours versus the estimated hours was needed. An easy way to do this is by setting up an effort registration table. The effort registration table would be updated every week to indicate how many estimated person hours is left of the phase. In the table below '**E**' notates the estimated person hours while '**A**' the actual hours.

Group no: 10 Date: November 23, 2011						
Activity / Period	35-37	38-40	41-42	43-44	45-47	Activity sums
Planning	**E:200** A:149	**E:0** A:61				**E:200** A:210
PreStudy	**E:200** A:131	**E:0** A:50				**E:200** A:181
Implementation		**E:475** A:254	**E:315** A:203	**E:315** A:220		**E:1105** A:677
Report	**E:125** A:94	**E:50** A:80	**E:35** A:91	**E:35** A:58	**E:295** A:497	**E:540** A:820
Period sums	**E:525** A:374	**E:525** A:445	**E:350** A:294	**E:350** A:278	**E:295** A:497	**E:2045** A:1888

Table 2.1: Effort Registration Table

2.2 Risk Management

To every project and team there are risks. In this section we will identify, characterize and assess situations that may occur during the project. The assessment is based on previous group work experiences.

2.2.1 Risk Assessment

To assess the risks we evaluated their potential severity of impact and their probability of occurrence. The consequences and probability (P) are said to be either low (L), medium (M) or high (H).

Id	Case	Consequences	P	Strategy	Responsible
R1	**Illness** A group member gets ill during the project	**M**: Increased workload for the rest of the team	**M**	Reduce - Assign delimited tasks to the ill person	Project manager
R2	**Comm. problems** Communication with the customer/advisor/-group members	**H**: The quality of the project results will decrease	**M**	Avoid - Double check and make sure that everyone is on the same page with meeting summaries	Everyone involved
R3	**Internal team conflict** Group members disagree or dislike each other	**M**: The quality of the project results will decrease	**L**	Avoid - Do ice breaking exercises and let everyone have their say	Everyone in the team
R4	**Lack of experience** Project introduces new concepts	**M**: The project is more prone to time expensive mistakes	**H**	Accept - Be thorough in the pre-study phase and utilize the advisor well	Everyone in the team
R5	**Incorrect requirements** Misunderstandings regarding the requirements	**H**: The quality of the project results will decrease	**M**	Avoid - Double check and make sure that everyone is on the same page with meeting summaries	Design leader, quality assurance manager, implementation leader
R6	**Dropouts** One or more group members drop out of the course	**H**: The quality of the project results will decrease	**L**	Accept - Divide the extra workload among the rest of the team and try to cope with the reduction in staff	Project manager
R7	**Wrong priorities** One or more group members fails to do their tasks	**L**: The quality of the project results will decrease	**L**	Avoid - If a member of the team recognizes that another member of the team is not pulling his own weight because his priorities lie elsewhere, the project manager should be involved in order to resolve the issue	Project manager

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Table 2.2 – continued from previous page

Id	Case	Consequences	P	Strategy	Responsible
R8	**Oversleeping** One or more group members fail to attend a meeting because they overslept	**L**: The team has to waste their time by updating the oversleeping team members after the meeting	**M**	Avoid - Tell the oversleeping team members that they have to pull themselves together. If it continues, threaten to involve course staff	Project manager
R9	**Technical issues** Failure of technical components	**M**: The quality of the project results will decrease	**L**	Accept - Try to get hold of substitute equipment	Nobody
R10	**Delayed deliveries** The delivery of necessary tools and resources to the team is delayed	**H**: The quality of the project results will decrease	**M**	Accept - Focus the team's efforts on activities that can be done without the delayed resources	Nobody

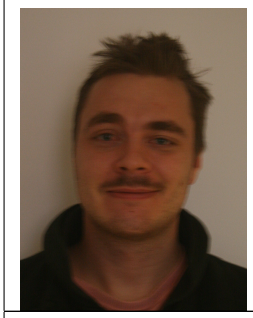
Table 2.2: Risk Assessment

2.3 Project Organization

The success of a project relies heavily on its organization. A structured work and information flow increases productivity and motivates the group members to make a better effort.

2.3.1 Roles

In order to get a structured work flow, roles are assigned to each group member. Each role consists of related tasks that together creates a routine. In addition to the resposibilites that comes with the specific roles, each one of us will contribute where we can, be it coding or writing the report.

	Person	Role	Description
	Sondre L. Sæter	Project Leader	The project leader should resolve group conflicts, be a common contact person and make sure milestones are reached in desired time. He will be the one who checks and documents the group members' work hours.
	Eirik Stene	Document manager	The document manager is responsible for the general quality of the deliverable documents.
	Roar Bjurstrøm	Test leader, Requirements responsible, Modelling designer	The making of a test plan and coordinating the testing of the system, is the main responsibilities of the test leader. The requirements responsible makes sure that the requirements specification correspond to the customer's needs at all times. The modelling manager is responsible for the quality of the models and figures that are to be included in the documentation.
	Kato Stølen	Design Leader	The responsibilities of the design leader is to coordinate the design phase. This person has the final say in decisions regarding the architecture of the system.

Continued on next page

Table 2.3 – continued from previous page

	Person	Role	Description
	Robert Versvik	Implementation Leader	The implementation leader makes sure that we follow the planned architecture and design of the system, in addition to ensure that we do not exceed the allotted time of the implementation.
	Sonik Shrestha	Quality Assurance Manager	The quality assurance manager makes sure we have identified the relevant product qualities, and that the design and implementation realize these.
	Bjørnar Valle	Secretary	The secretary takes notes and writes summaries from all the meetings, and sees to that everyone included gets a copy. He also organizes notes and questions ahead of the meetings. The secretary takes the lead in the project manager's absence.

Table 2.3: Project Roles

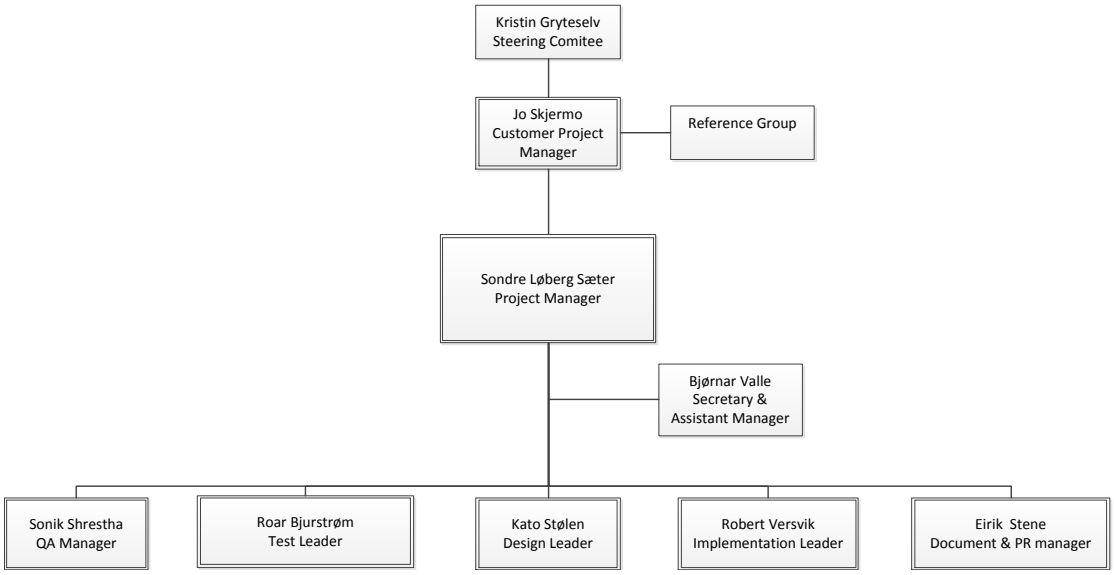


Figure 2.2: Organization Chart for the Project

2.3.2 Weekly Schedule

A week consists of one meeting with the customer, one meeting with the group advisor and five Scrum meetings. In addition to the five scheduled Scrum meetings, every team member available should gather and work on the project every weekday.

Day	Time	Location	Description	Attendees
Monday	10:15 - 10:40	P15, 4th floor	daily Scrum meeting	Everyone available
Tuesday	**10:15 - 11:00**	**ITV-464**	**Advisory meeting**	**All**
	11:15 - 11:40	P15, 4th floor	daily Scrum meeting	Everyone available
Wednesday	10:15 - 10:40	P15, 4th floor	daily Scrum meeting	Everyone available
Thursday	10:15 - 10:40	P15, 4th floor	daily Scrum meeting	Everyone available
	13:15 - 14:00	**iArbeid**	**Customer meeting**	**All**
Friday	10:15 - 10:40	P15, 4th floor	daily Scrum meeting	Everyone available

Table 2.4: Weekly Meetings

2.4 Planning for Quality Assurance

In every project, quality assurance can help ensure a good result. Therefore we decided to follow certain processes and routines, which will be introduced in this section.

2.4.1 Internal Routines

To handle the internal work, we decided on some routines to give a good basis for group communication and efficient work scheduling. The routines were as follows:

- Daily internal meetings will be used to distribute tasks and update each other on what have been done since last time. More information can be found in the Meetings section below.
- Everyone should work Monday to Friday from 10:15 to 15:15. If something prevents this, the lost hours should be caught up on the spare time. This will ensure that we get the estimated 25 work hours per person each week.
- To keep in touch with each other while working, Skype will be used as an instant online messenger.
- E-mail will be used for sending out information for anything particularly important or out of the ordinary.
- If someone is late, they will be contacted on their mobile phone.

2.4.2 Meetings

- **Internal meeting**
  Every day at 10:15 we should have a short meeting. These meetings will be used to distribute tasks and update each other on what have been done since last time. Due to other meetings, we will have different meeting hours when we are to meet up with our advisor or our customer.
- **Advisor meeting**
  Each week we will have an advisor meeting. This meeting takes place every Tuesday in room ITV-464 at 10:15. After this meeting we will have our daily internal meeting.
- **Customer meeting**
  Our customer meetings are usually scheduled for Thursdays. They will for the most part take place in iArbeid at 13:15. After this meeting we will have our daily internal meeting for Thursdays.

2.4.3 Templates

For regular documents we produced a set of templates. This was to ensure that they contained all the necessary information, make it more efficient and to keep a certain standard. The templates we used were:

- **Status Report**
  Every week we wrote a status report for our advisor. This was to give him a clearer view of how the last week had been, describing positive and negative experiences, and each person's hours for the respective week. This was delivered to the advisor together with a full updated version of the report and meeting agenda.
- **Meeting Agenda**
  This was a document containing time and place for the meeting and information about what should be discussed. Name and phone number of every attendant was also added.
- **Meeting Summary**
  This document contained the names of attendants, time and place and a summary of the meeting.
- **Worksheets**
  To keep track of the person hours for each week, we created a spread sheet template where we could fill in our work hours.

The templates can be found in Appendix B: Templates.

2.4.4 File and Document Management

To ensure safe storage and easy use, we used some tools to handle our files. For our report we used LaTeX and Dropbox. For our coding and implementation we used Apache Subversion, and for the templates we used Google Docs. These technical tools will be described in the Preliminary Study chapter, section 3.5.

2.4.5 Task Reviewing and Inspection

When a person has written a text, it can be quite difficult for him to go back and identify parts of the text that should have been better. As humans we tend to have a hard time identifying and acknowledging our own flaws or mistakes. This principle is true for a lot of things in life. In order to deal with this problem and maintain a high level of quality throughout our project work, we assigned reviewers to all work tasks that were delegated. We decided that each piece of work of each group member should be inspected by another group member. [13]

For each chapter in the report we picked one group member to be responsible for the overall quality of the chapter. The tasks of the chapter responsibles will be to make sure that everything is consistent and correct, and in the end to do a final review of the chapter.

2.4.6 Customer Interaction

In addition to the meeting, the customer interaction was done either through phone calls or mail.

- **Mail**
  - **Meeting agenda**
    The day before each meeting, we sent the meeting agenda as an attachment.
  - **Meeting summary**
    The meeting summary was sent by mail as soon as it was written.
  - **Questions**
    Questions with no immediate need of an answer were sent by mail.
- **Phone**
  - **Questions**
    Questions that needed an immediate answer was taken over the phone.

2.4.7 Advisor Interaction

Our interaction with the advisor was mainly done during the meetings. Other than the meetings, we had three ways of interaction with our advisor. They were:

- **Mail**
  - **Meeting agenda**
    The day before each meeting, we sent the meeting agenda as an attachment.
  - **Meeting summary**
    The meeting summary was sent by mail as soon as it was written.
  - **Questions**
    Questions with no immediate need of an answer were sent by mail.
- **Visit the Advisor's Office**
  During work hours, the advisor was usually at his office if we had any questions. This option was used for extra reviews of the report, technical advice or other sensitive questions.
- **Phone**
  Questions that needed an immediate answer was taken over the phone.

3 Preliminary Study

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In this chapter we will explicitly describe the problem that we are facing and the possible solutions. Technologies that will be used during the project will also be presented.

3.1 Problem and Solution Space

In this section the problem and solution space are addressed in form of the current and desired solution, together with the technological restrictions from the customer.

3.1.1 Original Situation

This is a short description of the situation the NPRA was in when they came to us with their problem. The original project description from the customer can be found in section 1.2. The essence of their problem is that the important error messages that describe failures and/or errors in their system is cumbersome to manually collect from the "gathering installations", and that a "lack of overview" over erring hardware is costing them a lot of data. The hardware can have months of downtime, where it can give bogus data for a long time before the error is discovered, making the data highly unreliable. Below is a detailed illustration of their current system.

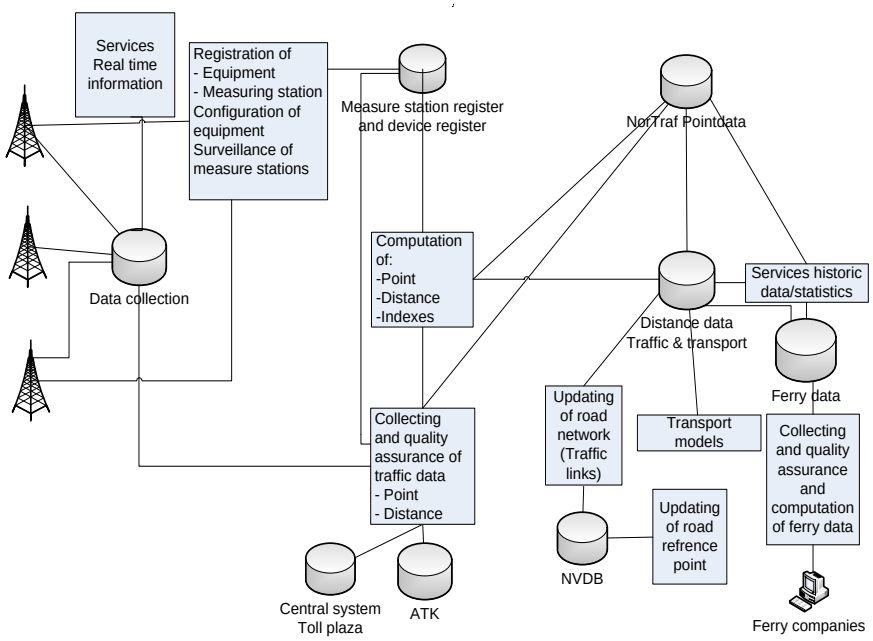

Figure 3.1: Original System at the NPRA

3.1.2 System Expansion

This section contains a short high level description of the extensions that we are going to make to their system. Our main objectives are to make the Datarec 7 hardware automatically send the error messages to their systems so they do not have to manually collect it, and to send automatic notifications about any errors that should occur.

Our customer asked for a real-time system that continuously checks the data from the Datarec 7 for errors, because it is important to fix them as soon as possible to avoid gathering bogus data. Datarec 7 offers an Ethernet connection, which makes the fetching of real time data much faster. In our development period we will have access to one roadside counting station, where we will place a server laptop. On this laptop we will

implement a server that frequently pushes the gathered data to another computer, which can be one of our own personal computers, or a computer at the NPRA's offices. This is where the data will be processed by an implementation that we have called the Error Handler. The Error Handler should have the functionality to catch errors and insert a new entry with all the relevant information into a database.

This is where our so-called Web Service comes into play. When a new entry is put into the database, the Web Service pulls it out and feeds it to a web page. The web page displays the current state of the roadside installations. A state log is displayed in a clear interface. Since the history of an installation can be viewed in the state logs, the manual pre-processing of the data is reduced. If the logs state no errors for a specific installation, the data can be used straight out of the box, and in case of hardware errors the real-time notification system reduces the downtime of installations. Installations with hardware errors would be displayed on a map.

Together with the customer, we agreed upon the following dataflow model of the system extensions:

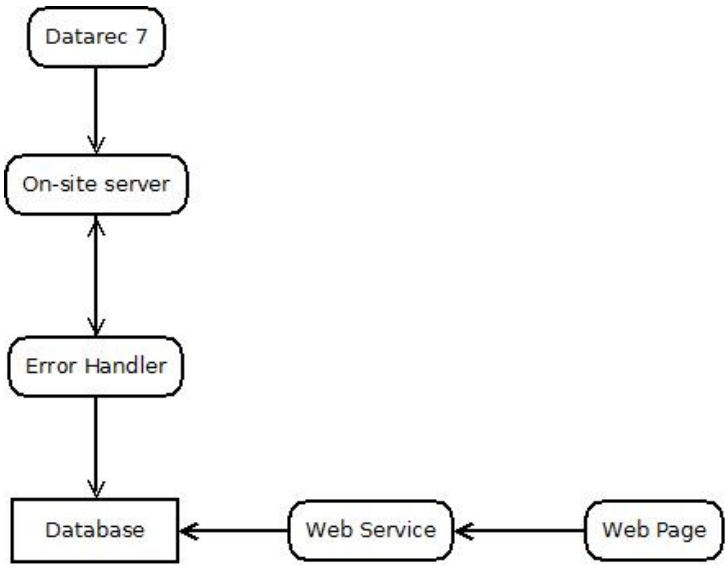

Figure 3.2: Dataflow Model of the System Additions We Are Making

Overview of the system extensions

Actor:	**Datarec 7**
Description:	Vehicle classifier used to register road traffic
Examples of actions:	Fetching roadside data and sending it to the ONSITE server

Table 3.1: Datarec 7

Actor:	**ONSITE server**
Description:	A server placed on-site
Examples of actions:	Continuously reads the hardware status from Datarec 7's SOAP interface and notifies if an error occur

Table 3.2: ONSITE Server

Actor	**Error Handler**
Description:	An Java-application installed on a server used to handling errors
Examples of actions:	Create warnings on irregularities and peculiar data, from Datarec 7

Table 3.3: Error Handler

Actor	**Datarec Database**
Description:	A SQL database to store statuses and errors
Examples of actions:	Store the errors fetched by the ONSITE Server

Table 3.4: Datarec Database

Actor	**Web Service**
Description:	The access point to the system
Examples of actions:	Access the errors from the database and send coordinates to the Web Page

Table 3.5: Web Service

Actor	**Web Page**
Description:	Displays web pages containing digital assets
Examples of actions:	The user interface displaying unit state information and map images from the Map Service

Table 3.6: Web Page

3.1.3 Solution Space

The customer gave us a number of requirements that were taken into consideration. This was done so that the customer can integrate the solution into their systems. We were expected to use Java or Java EE for the project, and all data communication should be done with SOAP XML. In order to fit the student-made system into any existing systems, we needed to make a web service. Another requirement the customer had, was that if an error occurred on a roadside installation, the location of the installation should be displayed on a map.

In a future system the roadside installations would all be connected through fiber or Ethernet, but in today's system most of them are connected to the 3G network, or even modems. The 3G network, with its max capacity of 500 kbps, has limited bandwidth and the time it takes to connect to a unit is considerably higher than through fiber or Ethernet. To improve the performance the customer suggested that they could put a mini-PC on-site, which would continuously read the status of the units and notify if any hardware errors occur. This mini-PC would run a server pushing data to a client that would parse it for database storage. The customer had originally requested that we would implement this server in OPC-XML, but we discovered that OPC-XML did not offer all the functionality that we needed. The server would instead be implemented with functionalities that mimics OPC-XML.

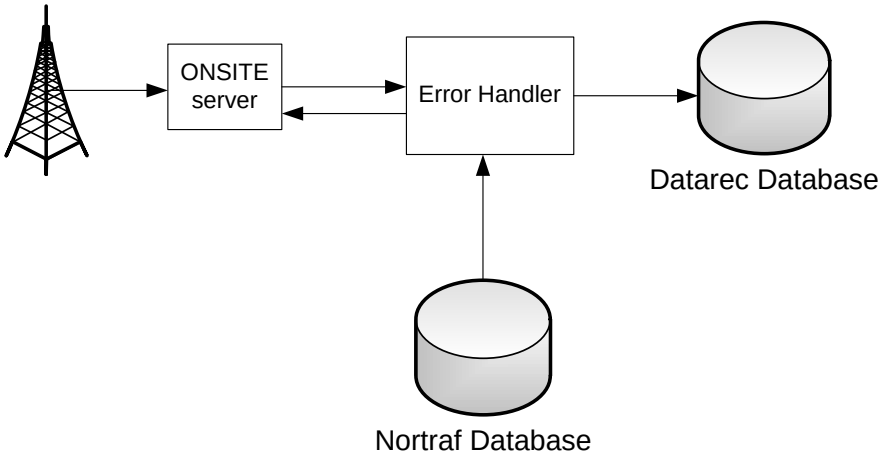

Figure 3.3: Data Flow: Error Handler and ONSITE Server

A laptop PC hosting a server is placed on-site. This server continuously reads the hardware status through the Datarec 7's SOAP interface and notifies if an error occurs. The error handler listens for notifications from the on-site server and parses them for database storage. To give access to the error notifications in the database, a web service needs to be set up. The web service will be the access point of the system.

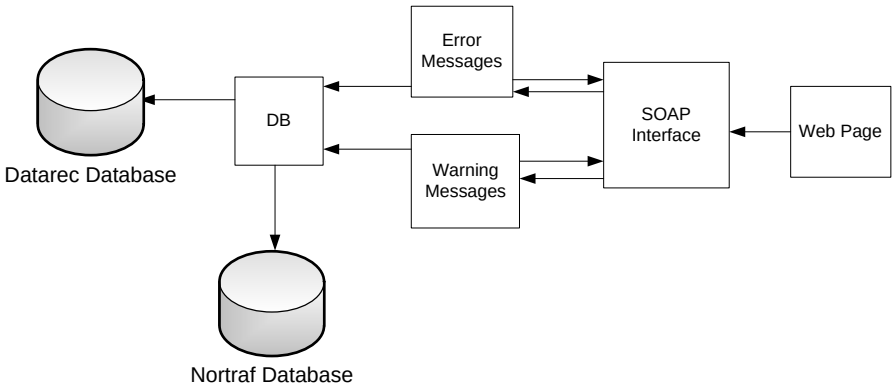

Figure 3.4: Data Flow: Web Service

The map service will use the web service to display installations with hardware error on a map.

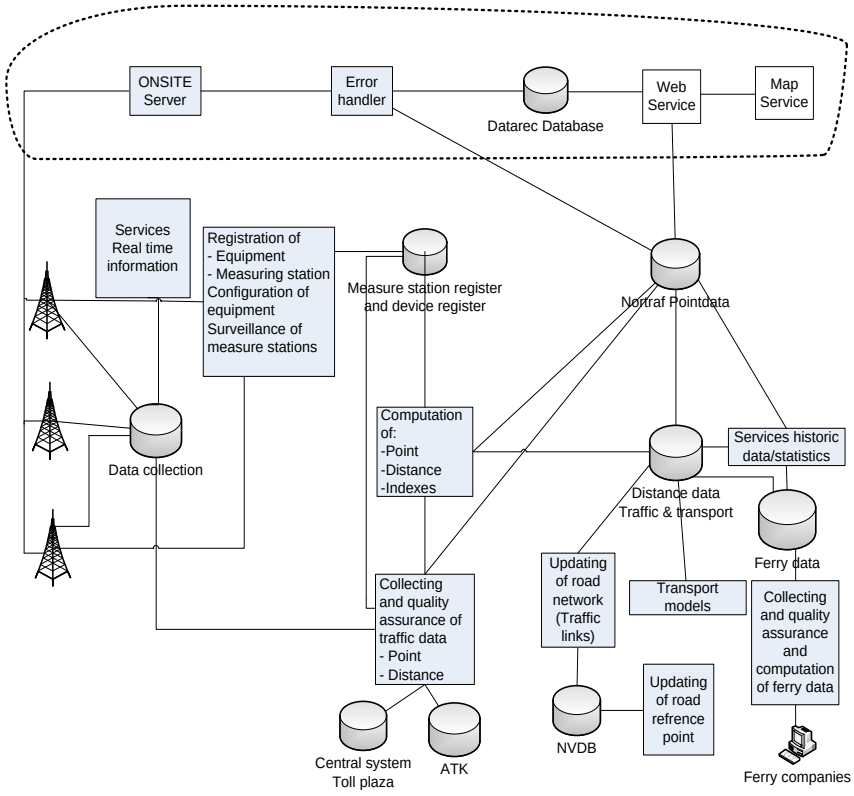

Figure 3.5: The Future System with Our Extensions

3.1.4 Existing Solutions

Systems such as these are usually tailored to the customer's existing systems. For the Datarec, there to be an existing off-the-shelf solution to the entire problem, due to the fact that NPRA asked us to make a proof-of-consept system. The solution consists of several systems: one that checks the roadside installations for hardware errors, one that acts as a web service providing access to the data from the error checking, and one that uses the web service to display the information. The system that checks for hardware errors might become obsolete if the hardware vendor decides to implement some kind of self-diagnosis in the future. The rest of the systems can be modified to support the changes.

The UK National Traffic Control Centre exposes some of their traffic data using a solution based on the Datex II standard. Through this solution it is possible to get a list of current and future roadworks, events, loop-based data and more. Users can also query data for a specific location they are interested in.

3.2 Field Excursion

We got an invitation to join Jo Skjermo and some technicians for a field trip to check out the roadside equipment. They were going to install a Datarec 7, a server laptop and an ICE-modem at their "counting site" in Moholtlia. Usually their roadside installations do not include server laptops and ICE-modems, but for the software that we will implement, they were both necessary.

The Moholtlia site is usually not "operational". The NPRA only install their Datarec 7 hardware at this site for about four weeks every year to get a sufficient "coverage" of this road (Omkjøringsveien). However, for our testing purposes, the Datarec 7 was to remain at the site for the rest of the year. Unfortunately, due to some technical problems we had to go on another excursion in mid November to move the Datarec 7 from Moholtlia to the graphics lab at NTNU.

Bjørnar and Sondre were the two students that joined to see where the installation site was, how it looked and to take some pictures.

Figure 3.6: Excursion - Technicians and Jo Skjermo

The excursion lasted for about two hours. When both the computer and the ICE-modem were set up, student Bjørnar called the students whom were working at the school to test the connection. Before everything was working properly, three tests were needed.

1. The first test was to make sure that the connection worked. For this test both the computer and the modem were outside the roadside cabinet. The connection worked fine, so the modem and computer were placed inside of the cabinet.

2. The second test was to see how the connection was affected by the cabinet. The test did not go well. It showed a connection close to non-existing. We managed to connect, but it was too slow to get anything done. The reason for this problem was probably that the cabinet acted as a Faraday cage **??**. As a solution to this problem, the antennas of the modem were angled so that they physically touched with the cabinet itself.

3. The third test went well. Since the cabinet was made of metal, it made it possible to send and receive. Now we had a good connection, and the hardware was safely in the cabinet.

The road monitored by the Datarec 7 in Moholtlia is Omkjøringsveien. It has four lanes, which gives us readings from eight induction loops. It is also in a position that has continuous traffic.

Figure 3.7: Excursion - Cabinet and Datarec 7

Figure 3.8: Excursion - Cabinet, Datarec 7, Computer and Modem

3.2.1 Extra Excursion

During the last three weeks of our project we were unable to connect to the hardware that we had installed in Moholtlia. After a week or so of no connection, customer representative Jo Skjermo drove up to the site to try and fix the problem. Unfortunately the problem was not fixed, and we had to try again. Sondre Sæter met up with one of the

technicians whom we met at the first excursion, and tried to fix the problem by adjusting the modem antennas. We did not manage to get a good connection, and decided to bring the hardware to the graphics lab at NTNU. After we had installed it in the lab, the connection worked well, and we could finally test our system with errors from the real Datarec, instead of the mockup.

3.3 Testing

The system needs to be extensively tested before it is delivered to the costumer. The testing is to ensure the reliability of the software, and to ensure that the software fulfills the requirements from the costumer.

3.3.1 Test Methods Used During the Project

Black Box Testing

Black box testing is a test method where inputs are checked to see if they produce a valid output. This testing method does not look into the internal structure of the program, but ensures that the external structure is correct. The tester should not be required to have any knowledge about the internal structure of the program. For this method to be effective, it is important to select input at critical areas, such as the edges in the input domain. This method is effective for testing the system against its requirements.

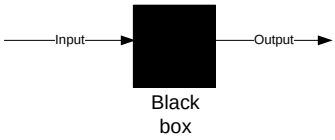

Figure 3.9: Black Box Testing

Test Driven Development

Test driven development (TDD) is a software development process where the developer makes automated unit tests before writing any actual code. The unit tests are small, and consist of valid input and output to a part of the program. The input and output are tested against each other when a test is run. The developer produces the code which passes the tests, and then starts making new tests and a new cycle starts. One drawback with the process is that the developer has to write more code, but this process also often helps the project use less time debugging. The code often is very modularized, since the developer has to make each part of the program from small independent tests.

3.4 The Hardware

As we introduced in chapter one, there are two important pieces of hardware in the NPRA's roadside installations. These are the Datarec 7s and the induction loops. The prototype we are developing in this project is built around them. In this section we are going to take a closer look at how they work.

3.4.1 Datarec 7

Datarec 7 Signature is the name of the hardware that is used by the NPRA to register traffic. It both counts vehicles and processes error messages. The traffic registration is based on an inductive loop technology that utilizes the inductive pattern recognition of a vehicle's electronic signature to identify which type of vehicle is driving by. The system is based on a Windows CE operating system, and has a LAN interface that it can use to communicate with other devices.

More explicitly, the information that you can gather with the Datarec 7 involves the volume, velocity, length, occupancy (how much time it takes from the nose of the car enters the first loop till the very back of the car has left the second loop), time headway and time gap of the vehicles passing by. This data can be registered for one vehicle, or for the average value over 5 minutes, 15 minutes or 1 hour.

The Datarec 7 can be accessed through its SOAP interface with a number of requests. Below is a list which presents the different requests that Datarec 7 responds to, as well as a short explanation of how we used them.

- LOOP_CONNECT is used to check the status of the Datarec 7's connection to its loops. If the connection status is not as it should be, an error has to be raised.
- LOOP_HITS returns a string with the number of "loop hits", meaning how many vehicles have driven by the inductive loops that the Datarec 7 is connected to.
- LOOP_FREQ returns a string with the frequencies of the loops that are connected to the Datarec 7.
- START returns the start time of the Datarec 7 interface.
- BATTERY returns the battery voltage of the Datarec 7 in mV. This is checked against a minimum and a maximum value. If the value is outside one of these, a warning message is sent.
- TEMPERATURE returns the temperature of the Datarec 7 device in degrees Celcius. This is checked against a minimum and a maximum value. If the value is outside one of these, a warning message is sent.

- VEHICLE returns the data of the most recent vehicles detected by the loops. It can return data for any number of vehicles from 0 up to 10.
- VEHICLE_ACC returns accumulated number of vehicles and their mean speed during a specified time interval.

Figure 3.10: Datarec 7 Signature

Version 4183	8 loops, up to 4 lanes
Version 4650	12 loops, up to 6 lanes
Dimensions	290x220x65mm
Hardware interface	Ethernet 10Mbit, RS232
Software interface	Web server, FTP server, SOAP
Sensors	8 or 12 inductive loops
Temperatures	Full operation -40C to +85C
Power	9-15V
Current consumption	12V/35mA average
Environment	IP65
Display	2 lines, each 8 characters
Data styles	Interval and/or vehicle by vehicle
Data output	Count, time gap and headway, occupancy, length, vehicle type classification

Table 3.7: Technical Information

3.4.2 Induction Loops

The Datarec 7 gets its data from a number of inductive loops which are installed under the asphalt. For each lane in the road there are two loops, as illustrated below.

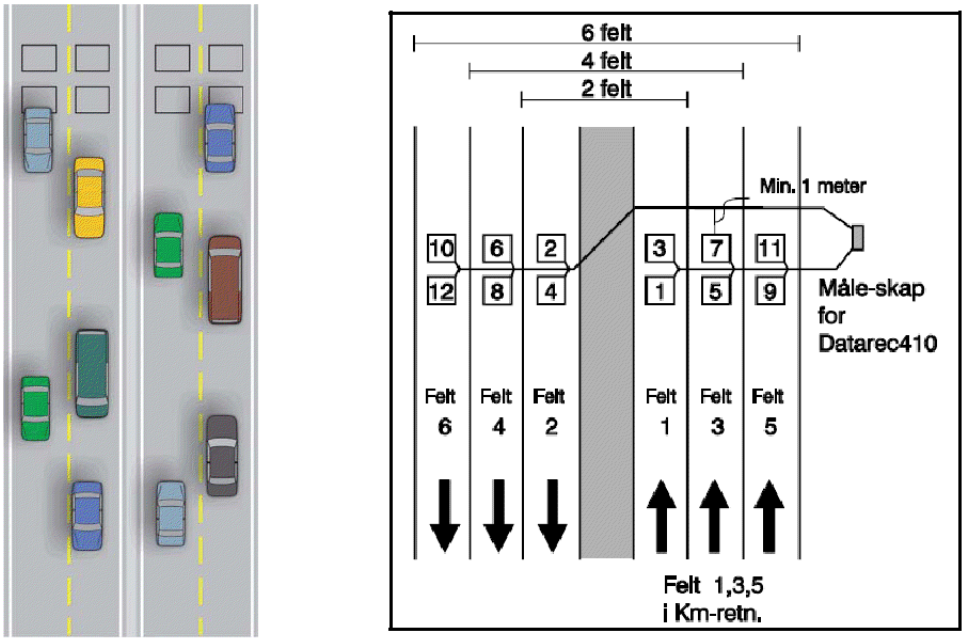

Figure 3.11: Datarec - Induction Loops

In addition to counting each vehicle that drives by, these loops also gather data about velocity and more, as mentioned earlier. They register the times for when a vehicle passes the first and the second loop, and then simply calculate its speed with the v = d/t formula.

3.5 Technologies Used During the Project Period

The customer had some restrictions on what technologies we could use. Most of them were known to us, but not all. In this section the technologies will be presented with a short description. Some of the technologies turned out to be redundant midways in the project.

Organizational Tools

In this section the tools we used to organize our files used during the project period.

Google Docs

Google Docs is a web-based office suite. It is a free service offered by Google. With Google Docs it is possible to collaborate on documents in real-time with other users. The service supports the creation of normal text documents, spreadsheets and presentations. We started using this because it would allow us to cooperate on documents. We also use it to write down our work hours in a spreadsheet. [17]

LaTeX

LaTeX is a document markup language, a modern system for annotating a text in a way that is syntactically distinguishable from that text. It is primarily used to translate XML-based formats to PDF. LaTeX uses the TeX typesetting program, which is a multiplatform typesetting system designed by Donald Knuth. Using LaTeX, the user is able to focus on the content of what they are writing, instead of how it looks, since LaTeX takes care of the visual presentation of structures like sections, tables, figures, etc. [18]

Dropbox

Dropbox is a Web-based file hosting service provided and operated by Dropbox, Inc. It uses cloud computing technology which make users able to use file synchronization to store and share content in repositories across the web. [20]

Subversion

Apache Subversion (SVN) is an open source cross-platform version control system founded in 2000 by CollabNet, Inc. By using Subversion developers are able to work with current and previous versions of files, mainly source code, web pages and documentation. Current release is version 1.6.17, and language used to develop Subversion is C. [21]

Test Tools

JUnit

Unit testing is a method of testing software, where a unit is tested by itself against expected results. A unit in Java tends to be a class or interface. Unit testing helps keep classes modifiable, facilitating refactoring without breaking the system through regression testing. Developers are able to simply run the tests to see if their refactoring broke the class, fixing the new bugs that appeared before committing the new code.

We opted to use the JUnit testing framework for unit testing in Java. It would be used to test the changes made, and if the system works.

Mockito

"Mocking/Stubbing" is a way to simplify unit testing by making "fake" versions of classes that the class being tested depends on. The fake versions has the same interface as the real thing, but will only return set values instead of doing any logic. This way the unit being tested is isolated, and only the logic is of the unit under scrutiny. There are quite a few mocking frameworks for Java that handle the creation of mocked classes, easing the workload on the users.

We decided to use Mockito as a mocking framework. Mockito made it possible to test parts of the program before it was finished, and it makes it possible for the program to make function calls to functions which have not yet been implemented. This functionality was the reason for our decision to use Mockito.

Technologies Used for Implementing

Java

Java is an object-oriented programming language designed by Sun Microsystems. Java code compiles to Java byte code, which can be run on the JVM. This makes Java a platform independent language. Java is used in a wide specter of applications, examples include web-servers, databases, web-frameworks and more.

Java makes it possible to write a project that can be run on any platform due to the Java Virtual Machine. This makes it very portable compared to using other languages like C# that are competing in the same field as Java.

The customer specified Java as the preferred language for this project. Most of us had previous experience with Java.

Java EE is a set of libraries for Java to simplify making fault-tolerant, distributed and tiered applications based on modular components running on an application server. The libraries included in Java EE give an API for XML, JDBC, RMI, JMS, e-mail, web-services, etc. and define how to coordinate between these.[14]

In this project it is applicable due to the libraries that simplifies the making of web services that use for example SOAP. The SOAP-serving is handled through the JAX-WS technology.

XML

<?xml?>

XML is a markup language which makes it possible to structure data. The documents are readable by humans due to it being a text instead of binary, but structured in a way that is easy to read for a computer. The format is well-documented and widely used, ensuring that most languages have a parser readily available either through the standard library or through an easy to find download. The structure of the document is also well-suited for expressing metadata without changing the way the document is parsed.[7]

We used XML mainly because of the requirements from the customer, where it says that all files use XML to communicate. Some of us had experience with XML beforehand.

GlassFish

GlassFish is an open source application server project, and is intended for the Java EE platform. The project was initially started by Sun Microsystems, but is now sponsored by Oracle Corporation, and it is therefore also known as *Oracle GlassFish Server*. GlassFish supports all the different Java EE API specifications, like JDBC, RMI, e-mail, JMS, web services, XML and so on. This allows for creation of a portable and scalable application. [30]

We used GlassFish because it handles SOAP-calls for us, converting the XML-messages to a method call, and it is a tried technology. This saves us from having to implement the XML-SOAP message to method call-logic, which can be error-prone and somewhat complex, and it saves us from having to debug yet another component.

OpenLayers Library

OpenLayers™

OpenLayers is a JavaScript library that provides an API for including map services in a web page. The library has support for many features on the map service. The most

important features it offers for our project are support for web map service (WMS), navigation and markers. The OpenLayers API was chosen because it offered all the necessary functionality that this project needed, and also the API is well documented.[11]

SOAP

Simple Object Access Protocol (SOAP) is a remote procedure call-protocol often used in web services. It uses XML to communicate between server and client, defining a set of rules for encoding data-types, procedure calls and responses. The protocol does not define a method of delivery, but HTTP or SMTP are the two most commonly used.[24]

We were asked to use SOAP by the customer. Since it is the interface used by Datarec 7 to give continuously status report to the OPC server. Members of the group had experience with SOAP.

Redundant technologies

These are technologies that we went into the project thinking we would need, but later discovered that they were redundant.

OPC

OPC is a foundation dedicated to creating open standards for automation - in their own words: "OPC is to automation what printer drivers were to Windows." They have released several standards for communication between entities.[9] For this project we will be using OPC-XML Data Access, which was released as 1.0 in 2003. This standard uses SOAP and XML for communicating back and forth, following a schema defined by the OPC Foundation.[10]

The reason for using OPC came from the architecture described by the customer. The Norwegian Road Administration has scheduled an installation of a OPC-server to communicate with Datarec 7, and requested that we would create a 'mock-up' on a computer on-site.

OPC was not used after all. This was due to the realization that the standard did not offer functionality for pushing data, which was a must for this implementation.

SNMP

Simple Network Management Protocol is a protocol for managing devices that is connected to an IP network. The protocol consists of a set of data objects that are exposed

in form of variables, which describes the system status and configuration. These variables are just object identifiers (OIDs) mapped to a value. The information about the variables and the structure of the management data is defined in management information bases (MIBs). The variables can be read and set remotely. [22]

SNMP was not used after all.

RMON

Remote Monitoring is an extension to SNMP. RMON focuses on analyzing the unit's network traffic, and provides statistics that can be used in network analysis. The data is presented in the same way as SNMP, as object identifiers mapped to a value. [23]

Initially we were going to use RMON to fetch data from the network traffic and detect irregularities from the roadside installation, by request from the customer. However, this data is only available for Internet Service Providers, and as such we did not use it.

Traffic6

Traffic6 is a software used to administer different measuring locations along the road and terrain. It is used by the Norwegian Public Roads Administration to fetch data from the Datarec 7 and Datarec 410 hardware. It also includes checking the equipment and sensors, checking the clock in the equipment, control the data from Datarec 7 and Datarec 410, check if the data is registered correctly and storing logs. [1]

Technical Platforms

In this section we have created a matrix where we rate the importance of all the technical tools that we have used during the project period. Tools that have been very important to our project period are marked as high, while tools that could have been replaced by something else or offered non-critical functionality have been marked as medium or low.

Technologies	**Importance**	**Comment**
Student chosen software:		
Apache Subversion	High	Coding would have been a nightmare without this tool
Unit testing	High	Critical in the test-driven-development process

Continued on next page

Table 3.8 – continued from previous page

Technologies	Importance	Comment
Oracle	High	A requirement from the customer
Java (EE)	High	A requirement from the customer
XML	High	An absolute requirement from the customer
SOAP	Medium	The customer preferred that we used this
LaTeX	Medium	Using another tool would probably only have impacted aesthetic aspects of the report
Dropbox	Medium	Other (less practical) tools could have replaced its functionality
NetBeans	Medium	Offered some nice functionality, but could have been replaced
GlassFish	Medium	Comes with Java EE
Mockito	Low	Made our lives easier during implementation
MySQL	Low	Used to make our lives easier. Oracle is used in the final delivery
Google Docs	Low	GDocs made administrating tasks easier
Microsoft Visio 2010	Low	Could have been replaced by another tool
Gantt Project	Low	Could have been replaced by another tool
Customer provided software:		
Traffic Sp605 for Statens Vegvesen	Low	Only important for the Dr410
Windows 7	Low	Having coded in Java, the software is OS independent
Customer provided hardware:		
Datarec 7	High	Performing tests on the Dr7 was absolutely critical for our success
On-site computer	High	Our solution would not have been possible without this
ICE mobile broadband	High	Connecting to the two tools above was essential
Datarec 410	Low	Outdated, and therefore down-prioritized

Table 3.8: Technical Tools Matrix

3.6 Coding Conventions

The system that is to be developed will not be maintained by us, and in order to improve the readability of the source code, we agreed upon some coding conventions. Since we were required to use Java as programming language a good start would be to use the coding conventions that comes with it. These coding conventions address many aspects of writing Java code, such as the declaration of classes, interfaces and functions, the indentation and length of lines and naming conventions. It is common that integrated developer environments, such as NetBeans, encourages the use of the language specific coding conventions by providing suggestions, indenting new lines automatically and displaying warnings or errors when using the wrong naming conventions.

```
package no.vegvesen.<application>.<layer>;

import java.util.*;

/**
 * [Description of the class]
 */
public class Example {

    /** [Description of the constant] */
    public static final String A_CONSTANT = "constant";

    private String variable;

    /**
     * [Description of the constructor]
     * @param parameter [Description of the parameter]
     */
    public Example(String parameter) {
        variable = parameter;
    }

    /**
     * [Description of the function]
     * @return [Description of the returned value]
     * @throws Exception [Description of the exception]
     */
    public String function() throws Exception {
        return variable;
    }
```

```
}
```

Listing 3.1: Coding Conventions Example

3.6.1 Naming Conventions

The readability of the source code is also dependent on the naming conventions used. Below is a list of naming conventions we will use during this project.

- Packages should use the format: `no.vegvesen.<application>.<layer>`
- Classes should be nouns with the first letter of each internal word capitalized: `MySqlDatabaseDriver`
- Interfaces should follow the same rules as for classes, but beginning with a capital 'I': `IDatabaseConnection`
- Methods should be verbs with the first letter lowercase and the first letter of each internal word capitalized: `getUnitStatus`
- Variables should have meaningful rather than short names: `int upTimeMinutes = 34;` (Avoid: `int i = (k + m) * width;`)

3.7 Software Qualities

A system can have different qualities. Not all of these qualities can be combined fully, which forces the developers and designers to make trade-offs and choose the most important qualities. The ISO/IEC 9126 gives an overview of the six main qualities, which each consists of other, more specific qualities.

- **Q1 - Functionality**
  Functionality is the attribute that focuses on giving the customer what he or she wants. A system is supposed to satisfy the stated and implied needs of the customer, which can be quite tricky. Functionality consists of the following qualities:
  - **Q1.1 - Accuracy** The delivery of agreed effects or results.
  - **Q1.2 - Suitability** The appropriateness of functions for specified tasks.
  - **Q1.3 - Interoperability** The ability to interact with certain specified systems.
  - **Q1.4 - Compliance** Characterizing the systems adherence to standards, conventions and laws.

  - **Q1.5 - Security** The ability to prevent unauthorized access to program or data.

- **Q2 - Reliability**
  Reliability is the software's ability to continue working with the expected level of performance under certain stated conditions and for a certain period of time. Reliability consists of the following qualities:
  - **Q2.1 - Maturity** The frequency of failure due to software faults.
  - **Q2.2 - Fault Tolerance** The ability to keep a certain level of performance if there should be a software failure.
  - **Q2.3 - Recoverability** The ability to re-establish normal level of performance and recover data directly affected by failure.
  - **Q2.4 - Availability** Describes the systems ability to be operational when needed.
- **Q3 - Usability**
  Usability is the attribute describing the effort needed for use, and how the individual experiences the usage, for certain stated or implied users. Usability consists of the following qualities:
  - **Q3.1 - Understandability** The ability describing how logical and applicable the system is.
  - **Q3.2 - Learnability** The ability describing how easy it is to learn.
  - **Q3.3 - Operability** The ability that describes the effort needed for operation and operation control of the system.
  - **Q3.4 - Attractiveness** The degree of attractiveness, or likability, of the user interface.
  - **Q3.5 - Usability compliance** Characterizing the systems adherence to standards, conventions and laws relating to usability.
- **Q4 - Efficiency**
  Efficiency is the describes the systems correlation between its level of performance and the amount of resources needed. The conditions should be stated. Efficiency consists of the following qualities:
  - **Q4.1 - Time behavior** Describes response times for stated though-put.
  - **Q4.2 - Resource utilization** Describes the amount of resources used.
  - **Q4.3 - Efficiency compliance** Characterizing the systems adherence to standards, conventions and laws relating to efficiency.

- **Q5 - Maintainability**
  Maintainability is the attribute that describes the effort needed to make stated alterations or modifications. Maintainability consists of the following qualities:
  - **Q5.1 - Analyzability** Describes how easy it is to indentify the main cause of a failure.
  - **Q5.2 - Changeability** Describes the amount of effort needed to change the system.
  - **Q5.3 - Stability** The attribute that describes the systems sensitivity to changes.
  - **Q5.4 - Testability** Describes how easy the system is to test after a system change.
  - **Q5.5 - Maintainability compliance** Characterizing the systems adherence to standards, conventions and laws relating to maintainability.
- **Q6 - Portability**
  Portability is the attribute describing the ease of transfer between different environments. Portability consists of the following qualities:
  - **Q6.1 - Adaptability**
  - **Q6.2 - Installability**
  - **Q6.3 - Co-existence**
  - **Q6.4 - Replaceability**
  - **Q6.5 - Portability compliance** Characterizing the systems adherence to standards, conventions and laws relating to portability.

The definitions above are based on information from [33] and [2].

3.8 Development Method

Before a decision could be made on what kind of development method to use, there had to be done some research.

3.8.1 Scrum

Scrum is one of many agile methods for software development. It was originally meant for physical product development, but it has also been used much for management of

software development. When working with Scrum, there are three core roles: Product Owner, Team and Scrum Master.

- Product Owner
  This role represents the customer, and must ensure that the project is delivering something of value. The Product Owner often writes customer-centric items, like user stories, and make sure these are added to the product backlog. Every Scrum team should have a Product Owner. That role can be combined with being a normal developer, but should not be combined with being Scrum Master.

- Team
  In Scrum a team is often put together of 5-9 developers with cross-functional skills. They are the ones who do the actual work; analyze, design, develop, test and so on. Since the team is the ones doing the work, they are also responsible for delivering the product.

- Scrum Master
  The Scrum Master is not the team leader. He or she is supposed to be the buffer that keeps disturbing influences away from the team and removes any obstacles that can stop the team from being able to deliver the sprint goal. In addition to this, the Scrum Master is the enforcer of rules and should ensure that the Scrum process proceeds as planned.

Scrum is an iterative and incremental way of working. The main part of a Scrum process is the Sprints, which is the unit of development. The duration of a sprint varies between a week and a month. Before each sprint, there is a planning meeting, used to identify tasks from the product backlog and estimate the work effort needed. This is put into the sprint backlog. After a sprint, there should be a review meeting to find out what did not go as planned and how to keep that from happening.

Each Sprint should end with a new deliverable of the product. The product backlog is used to find out which features to focus on during the Sprint. It is not allowed to change anything on the sprint backlog during a Sprint. If any requirements are not completed during the Sprint, it is returned to the product backlog. When a Sprint is completed, the team is often required to demonstrate the software.

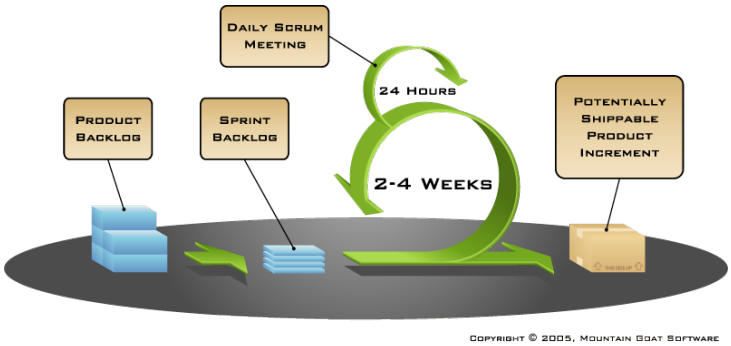

Figure 3.12: Scrum Model

In addition to the planning and review meetings, there is often a short daily Scrum status meeting. These are often called daily stand-up meetings, since everyone stands upright during the meetings. During these meetings every team member should answer three standard questions:

- What have you done since the last meeting?
- What do you plan to do today?
- Have you encountered any problems that may prevent, or delay, you reaching your goal?

Central in a Scrum project, there is a product backlog. This is a list of possible features ordered by business value. It is open to anyone, and has rough estimates on what amount of effort is needed for each feature. These estimates are used to find out which features have the highest Return of Investment, and therefore which features to prioritize.

One of the main ideas for Scrum, and other agile development methods, is that the environment or the customer's needs can change during the development. Therefore, Scrum takes on an empirical approach. Just accept that new or changed requirements can come, and focus on maximizing the probability of a quick delivery of the next increment.

[26]

3.8.2 Waterfall

The Waterfall method of development is to do the parts in sequence, and it is therefore called a sequential design process. The model was in 1970 described formally for the first time, though the term "waterfall" was not used. This article, written by Winston W. Royce, presented the model as flawed and non-working.

The model, as Royce described it, containes 7 phases:

1. Requirements specification
   In this phase, the specifications for the system that was going to be developed was found, prioritized and sorted. This should contain the customers explicit needs. Though very hard, it is important to cover the customers implicit needs as well.

2. Design
   The design should reflect the requirements, and make sure that the end result have the qualities that the customer wants in the system. The design includes :

   - General design
     This consists of the general architecture of the software. Different architectures have different qualities, and the choice of architecture will therefore affect the end result and the customer satisfaction.

   - Detailed design
     Often consists of class diagrams, use cases and BPMN to show the more specific parts of the system.

3. Implementation
   Implementation is the phase where the developers code the software. Also called Construction.

4. Integration
   Here the product is integrated with the existing system.

5. Testing and debugging
   Here the software is tested. This is done to find errors and to verify that the software does what the customer wanted. Also known as Validation or Verification.

6. Installation
   In this phase the software is installed for the end users and ready for use.

7. Maintenance
   This phase is the one where the end user gives feedback, often in the form of complaints. This feedback is used to remove more of the errors and improve the software further. This is a task often outsourced, since developers tend to dislike working on the same project for a long time.

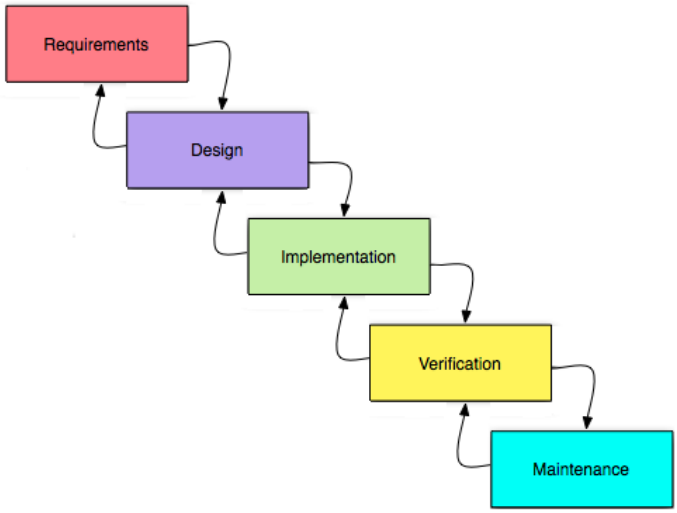

Figure 3.13: Waterfall Model

With feedback, the Waterfall model can become an iterative development model. It still consists of separate phases, but with feedback errors and opportunities for improvement is found. Then the needed phases can be started anew. [27]

3.9 Conclusion Based on Preliminary Study

As a result of the preliminary study we ended up with the product backlog (Table 3.9) and a choice of development method. The product backlog will act as a base for the requirements specification.

3.9.1 Table Properties

The requirements are prioritized after their importance in the project. The backlog items are rated with high, medium or low priority.

High priority indicates that the item is of high importance, and that the item is necessary to make the system acceptable for the costumer. These functionalities must be implemented, and will have the main focus during the sprints.

Medium priority indicates that the function is of some importance. Thes functions add functionality that the customer wants, but it is not an absolute necessity to complete the project.

Low priority indicates that the function is of little importance to the product. This means that the function will add some nice features to the system, but it is not crucial. Because of this, any functions with low priority will have low focus in the sprints, and will only be implemented if there is time left for it in the final sprint.

3.9.2 Product Backlog Table

The set of activities in the product backlog are listed in the table below.

ID	Description
	High Priority
1	Continuously fetch data from Datarec 7 installation
11	Set up on-site server
7	Make error handler
2	Save data in database
3	Set up web service
	Medium Priority
4	Show location of roadside installations on a map
5	Display unit information
13	Create installation guide
14	Display state logs for units
	Low Priority
9	Design web interface
6	Automatic notifications

Table 3.9: Product Backlog

3.9.3 Choice of Development Method

The decision of what development process to choose was discussed in detail within our group. We were initially set on following the waterfall model. The reason for this was that it is a quite simple way of working. With the waterfall model, the requirements specifications are set at the start and do not change. This seemed to be a fitting model since the needs of the NPRA does not change fast or often. So, from this, we had initially decided that the waterfall model would be a good and stable choice.

The customer though, through representative Jo Skjermo, expressed the wishes of Scrum as the model of development. The reason for this wish was the possibility of changes in the requirements specification. We then decided that since the customer wanted this specific model, we might as well agree to this. Gaining experience with the Scrum development model was also a reason to let go of the Waterfall choice.

Therefore the development method used in this project is Scrum. Since we decided to go with Scrum, roles needed to be assigned for the Scrum meetings. Bjørnar Valle was elected our Scrum Master, while Roar Bjurstrøm took the role of Product Owner. The rest of our project group were assigned to the Team.

As for meetings in Scrum, the decision was to have daily Scrum meetings. These would replace the internal meetings.

4 Requirements Specification

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4.4 Quality Assurance and Requirement Specification 49

This is the chapter where the various functional and non-functional requirements specifications are identified, discussed and explained. The customer came to us with a quite concise description about what properties he wanted the system to have. These properties were summarized in a product backlog (section 3.9). In order to fulfill the properties from the backlog, we defined a number of detailed system requirements, both functional and non-functional. The following tables contain the items from the product backlog in bold text, accompanied by the requirements specifications that have to be fulfilled for each separate item to be implemented. The functional requirements define the functionality that the system should have and the non-functional requirements defines constraints on how the functionality is supposed to be implemented. The requirements did evolve during the project due to changes in the costumers preferences, and we have documented these changes in appendix C.

4.1 Table Properties

The properties of the table concerning the requirement specification is identical to the table properties concerning the product backlog. These properties can be found in section 3.9.1.

Identification of each requirement is done by giving a requirement the letters FR or NFR, followed by a number. FR stands for Functional Requirement, and NFR stands for Non-Functional Requirement.

4.2 Functional Requirements

This section includes the functional requirements.

4.2.1 High Priority Functional Requirements

The following section contains all the functional requirements that were considered to be of high importance.

ID	Description	Priority
1. Continuously fetch data from Datarec 7 installations		
FR1	The system should support the Datarec 7 hardware	High
FR2	The system should use the SOAP interface to get the status of the Datarec 7 hardware every second	High
11. Set up the on-site server		
FR3	The server on-site should mimic a subset of the OPC functionality	High
FR4	The server on-site should be able to register listeners.	High
FR5	The server on-site should be able to push data.	High
12. Set up the Error Handler		
FR7	The Error Handler should be able to receive messages from the on-site servers.	High
FR8	The Error Handler should be able to register itself as a listener to the on-site servers .	High
FR9	The Error Handler should get a list of all the roadside installations and their IP-addresses from the NorTraf database abstraction level.	High
FR10	The system should use the data from on-site server to detect peculiar data, loop failures, hardware errors or wrong hard-wiring.	High
FR11	The errors should be separated from the regular data messages.	High
FR12	The Error Handler should create warnings on irregularities and peculiar data.	High
2. Save data in database		
FR13	The system should use a SQL database to store the statuses and errors.	High
FR14	The system should convert the messages from the on-site server for database storage.	High
3. Set up Web Service		
FR15	The system should have a web service using SOAP.	High
FR16	The Web Service should use the SQL database to offer status and error data.	High
FR17	The Web Services hould use the NorTraf database abstraction to get the coordinates of the roadside installations.	High
FR18	The Web Service should separate warnings and errors.	High

Table 4.1: High Priority Functional Requirements

4.2.2 Medium Priority Functional Requirements

This table contains all the functional requirements that was considered to be of medium importance.

ID	Description	Priority
4. Show location of roadside installations on a map		
FR19	The system should use a map service to show the locations of the roadside installations on a map.	Medium
5. Display unit information		
FR20	The system should display the status of separate installations in a web page.	Medium
14. Display state logs for units		
FR24	The system should store the states of the separate installations in a database.	Medium

Table 4.2: Medium Priority Functional Requirements

4.2.3 Low Priority Functional Requirements

This table contains all the functional requirements that was considered to be of low importance.

ID	Description	Priority
15. Automatic notifications		
FR25	The system should notify by SMS or email automatically if errors occur.	Low

Table 4.3: Low Priority Functional Requirements

4.3 Non-Functional Requirements

In this section the non-functional requirements are presented.

ID	Description	Priority
13. Create installation guide and user manual		
NFR1	The system should have a installation guide and user manual.	Medium
9. More extensive design of web interface		
NFR2	The web interface should have a clear design.	Low
NFR3	The web interface should use Ajax to enhance user experience.	Low

Continued on next page

Table 4.4 – continued from previous page

ID	Description	Priority
Other		
NFR4	The system should be programmed in Java/Java Enterprise.	High
NFR5	The system should be easy to integrate into the customer's existing system.	High

Table 4.4: Non-Functional Requirements

4.4 Quality Assurance and Requirement Specification

For this system, there are a few software attributes that stand out as more important than others. Because of the functinal requirements, the functionality of the system is one very important attribute. It is considered to be the most important attribute for this project. The non-functional requirements show that usability, portability and maintainability also are important. These attributes are coupled with non-functional requirements in table 4.5.

ID	Non-Functional Requirement	Quality in Use	Sub-attributes Used
NFR1	The system should have an installation guide and user manual.	Q3. Usability	Q3.2 Learnability
NFR2	The web interface should have a clear design.	Q3. Usability	Q3.3 Operability
NFR3	The web interface should use Ajax to enhance user experience.	Q3. Usability	Q3.4 Attractiveness
NFR4	The system should be programmed in Java/Java Enterprise.	Q6. Portability	Q6.1 Adaptability
NFR5	The system should be easy to integrate into the customer's existing system.	Q5. Maintainability	Q5.2 Changeability

Table 4.5: Mapping Non-Functional Requirement with Software Attributes

More information about each of these qualities and attributes can be found in section 3.7.

Part II Sprints and Implementation

5 Sprint Planning

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This section is dedicated to the planning of the implementation phase introduced in section 2.1.

5.1 Sprint Phases

The chosen life cycle model (3.9.3), Scrum, is built up of sprints. These are implementation phases with a presentation for the customer at the end. We chose to have three sprint phases to implement this project. The first sprint was planned to be over three weeks, while the two succeeding sprints should last 2 weeks.

The reason we chose to have three weeks for the first sprint was to get more work done before the first implementation presentation for the customer. This way we would get the time to actually implement a significant part of the system that is worth presenting.

There were several reasons behind the choice of three sprints.

- Project duration
- Minimal sprint duration
- Scrum experience
- Difference between scrum and waterfall

The project duration makes it a necessity to have relatively short sprints. The normal minimal sprint duration is two weeks. Therefore the last two sprints have a two week duration. The first sprint is a bit longer, three weeks. Three sprints would also give

us experience with Scrum deliverables and presentations. This, of course, in addition to the Scrum meetings, Scrum roles and Scrum planning. Another reason for having three sprints was that it had to be different than the Waterfall model.

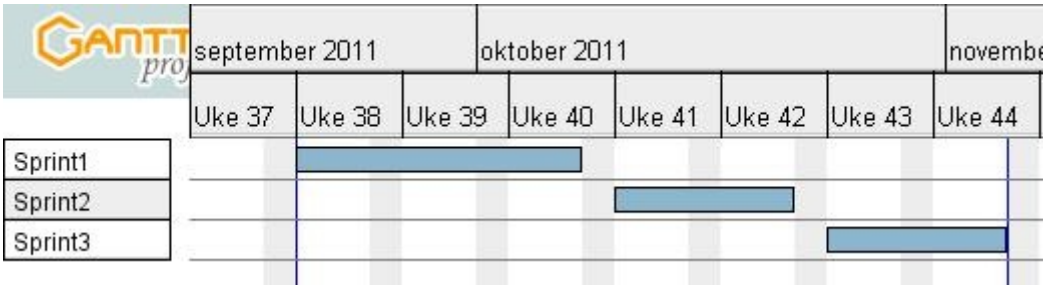

Figure 5.1: Gantt-Chart Diagram Describing the Sprints

5.2 Quality Assurance

This section will describe in detail what we agreed to do in order to ensure that its product held a high level of quality. It will also briefly discuss the choice of Scrum as development method in the perspective of quality assurance.

In quality assurance, the ultimate goal is to satisfy the customer. This fact advocates the choice of Scrum as development method, as the customer's needs may change at any given time of the project. Some old requirements may not be required at all, whereas some new requirements may come through. With Scrum, the group can incorporate as many changes as the customer wants even during the implementation phase of the project.

In the start of the implementation phase we appointed Bjørnar Valle and Roar Bjurstrøm as "Scrum master" and "product owner", respectively. The master lead the Scrum meetings, distributed work tasks, set deadlines and checked whether the team members did their tasks. The product owner came with suggestions and thoughts that preserved the customer's interests. After every sprint, we held an evaluation meeting, where we thoroughly discussed internally in our group what was negative and what was positive.

5.2.1 Milestones

"Within the framework of project management, a milestone is the end of a stage that marks the completion of a work package or phase, typically marked by a high level event such as completion, endorsement or signing of a deliverable, document or a high level review meeting." [31]

We have defined our project milestones to be identical with with the deadlines set by the

course coordinators, in addition to the ends of our project phases. Consequently, these are our project milestones:

Tasks	Duration (# work days)	Dependencies
T1 (Planning)	14	
T2 (Pre-Study)	14	
T3 (Sprint 1)	15	T1 and T2 (M1)
T4 (Sprint 2)	10	T3 (M2)
T5 (Sprint 3)	10	T4 (M3)
T6 (Report)	60	
T7 (Presentation Preparation)	3	T5,T6 (M4 and M5)

Table 5.1: Task, Duration and Dependencies

The different tasks are IDed by T1-7, and the different milestones are IDed by M1-5.

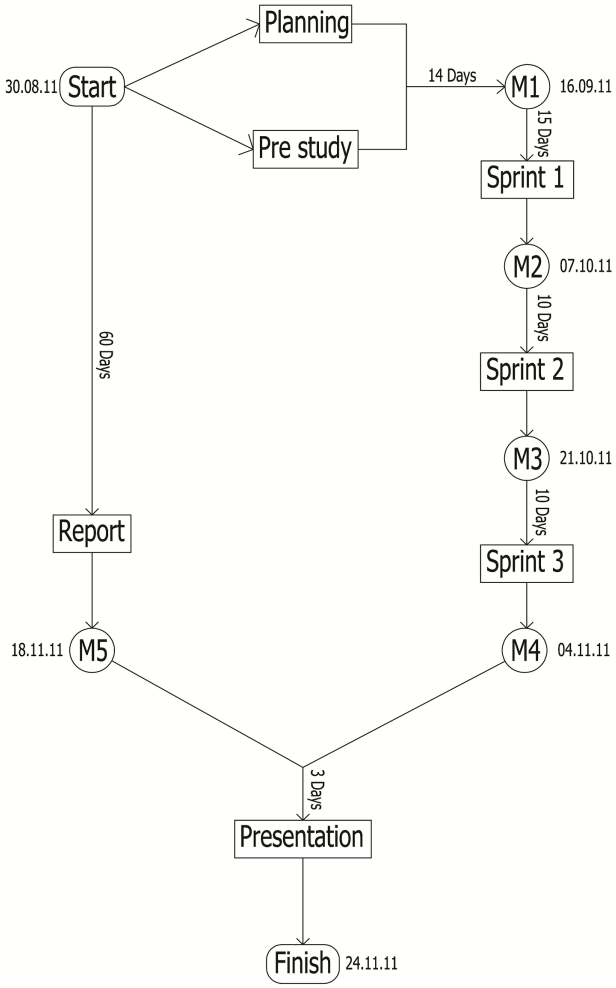

Figure 5.2: Activity Network Chart

Milestone	Preliminary Study and Planning (M1)
Goal	The main goals of this period was to get an overview of the problem and solution of the project, gather the customer's requirements, and plan our project period.
Quality Measure	The most important task of this period was to learn the overall overview of the project, get to know every group member, and prepare a product backlog.
Target Date:	16.09.11

Table 5.2: Milestone Table - Preliminary Study and Planning (M1)

s

Milestone	Sprint 1 (M2)
Goal:	The main goals for sprint1 were to design, implement and test the web page, web service, the Datarec 7 connection client and the database.
Quality Measure	The first task of this milestone was to implement good routines for daily stand-up meetings and distributing tasks efficiently. But most importantly, the purpose of this sprint was to implement, test and show the web page and web service to the customerl.
Target Date	07.10.11

Table 5.3: Milestone Table - Sprint 1 (M2)

Milestone	Sprint 2 (M3)
Goal	The main goals for sprint 2 were to implement the most significant parts of the on-site server and the error handler.
Quality Measure	The main task of this sprint was to set up an on-site server and implement most of the error handler.
Target Date	21.10.11

Table 5.4: Milestone Table - Sprint 2 (M3)

Milestone	Sprint 3 (M4)
Goal	The main goals for sprint 3 were to complete the implementations of the on-site server and the error handler. Other goals were to to make an installation guide and to improve the GUI of the web page.
Quality Measure	The major task of this sprint was to get on-site server and client communicating, complete all other remaining components of the system and perform an integration test and demonstrate the complete system to the customer. Above all get the customer's approval for the completion of project.
Target Date	04.11.11

Table 5.5: Milestone Table - Sprint 3 (M4)

Milestone	Report (M5)
Goal:	The final report has to include all the necessary chapters and should not be of more than 200 pages.
Quality Measure	The final draft of the report should be complete within the target date for the final approval of the advisor.
Target Date	18.11.11

Table 5.6: Milestone Table - Report (M5)

Milestone	Presentation (M6)
Goal	The final presentation should be prepared and completed at least one day before the deadline.
Quality Measure	Microsoft PowerPoint should be used for the presentation. The application should run and work with the device as it is expected to (consider MS office versions). All the members of our team must be involved in the presentation. The presentation should be given in front of the advisor, the customers, the examiner and others who are invited.
Target Date	The project should be presented on 24th November, 2011 at 0915 in ITV-354.

Table 5.7: Milestone Tentation (M6)

As shown in Figure 5.2, we have planned for a total of five milestones. We decided that each "deliverable" will replace the need for a milestone report. At each milestone, we have to make a deliverable to either the costumer (M2, M3, and M4) or the course coordinator (M5), except in the case of M1. M1 did not require a milestone report as it was purely a deadline we set for ourselves to finish our preliminary study and planning by.

Detailed planning of T3 (Sprint1), T4 (Sprint 2) and T5 (Sprint 3) has been explained in its respective sections (see section 6,7 and 8).

5.3 Product Backlog

This section contains the plan for which parts of the product backlog that were the conclusion of the preliminary study, the backlog can be found in section 3.9.

5.3.1 Table

This updated product backlog table describes the total effort estimate for each sprint and parts of the sprints, as well as which functional requirements (FR) or non-functional re-

quirements (NFR) fulfilled with each task. For more information about the requirements, refer chapter 4 - Requirements Specification.

ID	Description	Total Effort Estimate	Sprint 1	Sprint 2	Sprint 3	Req.
	High Priority					
1	Continuously fetch data from Datarec 7 installation	70	70	0	0	FR2
11	Set up on-site server	315	0	165	150	FR3-5
7	Make errorhadler	275	65	150	60	FR7-12
2	Save data in database	70	70	0	0	FR13-14
3	Set up web service	135	135	0	0	FR15-18
	Medium Priority					
4	Show location of roadside installations on a map	55	55	0	0	FR19
5	Display unit information	30	30	0	0	FR20
13	Create installation guide	40	0	0	40	NFR1
14	Display state logs for units	50	50	0	0	FR24
	Low Priority					
9	Design web interface	20	0	0	20	NFR2-3
6	Automatic notifications	45	0	0	45	FR25
	Sum Hours	1105	475	315	315	

Table 5.8: Product Backlog

5.3.2 Sprint 1

Sprint 1 mainly consists of implementing the database, web service, map service and the display of unit information. This was much due to the fact that we did not have access to the Datarec hardware in sprint 1. The database is not dependent on any other services for working properly. The web service, map service and web page get all the information they need from the database. Therefore by choosing to implement these parts first, we reduced the damage of the delay that threatened the project.

The implementations of unit information and map service were done in the web page; this also made it natural to implement them together. The database is a high priority service because it is where all the error messages are stored. The storage of error messages makes it possible to show errors after they occur, which is a crucial functionality. The web service is a high priority service, because it made the information in the database useful. It connects the errors with their location, and the data would be pretty useless if

the location was not stated. The functionality on the web page is important, because it makes the information visible to the user. But it is only of medium priority because the system does not depend heavily on it, and it would be enough to make a rather simple presentation of the data.

We also wanted to implement the SOAP client on the on-site server which makes it possible to continuously fetch data from the Datarec 7 early in the project. The reason for this was to ensure that any critical hardware issues were discovered early in the project, so that we had time to recover from them. Since we got access to the hardware rather late, we also added some time for this in sprint 2. The fetching from the Datarec 7 is a high priority functionality, because without it, it would be impossible to get data to the system, since almost all the information comes from the Datarec 7 hardware.

5.3.3 Sprint 2

The important functionality that needed to be implemented in sprint 2 was the error handler and the on-site server. The initial plan was to implement an OPC client and add a service that fetched network statistics. This was abandoned due to reasons explained in chapter C.3. It was important to implement the error handler and the on-site server in sprint 2, because with this part done, we actually would have a working system quite early in the project period. With a running system, it would be easier to test and to get a better view if anything else needed to be implemented. The error handler should initially have been done by the end of sprint 2, but since we added much more complexity into the error handler, we thought it would be a good idea to add time for finishing it during sprint 3. The on-site server is probably the most complex part of our project, and also needed to be extended into sprint 3. This means that it was not probable that anything was completely done during sprint 2.

The error handler is a high priority functionality, because it is this service that caches the errors. The on-site server is high priority because the customer wanted a system which pushes data. The Datarec 7 is not able to push data, but in the future the functionality of the on-site server should be offered by the roadside hardware. Therefore since we are making a prototype of the system, it is important that the system has this functionality.

5.3.4 Sprint 3

The on-site server and the error handler had to be finished during sprint 3, and with these parts complete, the system should be able to run. But in sprint 3, we also planned to implement support for automatic notifications via mail or sms, design the web interface in a more advanced way, create a user manual and add support for the Datarec 410. The plan was to finish the on-site server and the error handler, and then add functionality that

is not as critical for the project, but makes the system better. These additions would be added if there was time for it. The installation guide is needed to make the system usable for new users. This had medium priority in sprint 3. The support for Datarec 410 is a feature that will be added in sprint 3, and is a good feature for the system since most of the current hardware is of this sort, but since all new equipment is of the Datarec 7 type, it would not be a critical if it was not implemented. Therefore this had medium priority. Later in the project it was considered to be unnecessary to implement this feature, and it was therefore removed from the backlog. The initial backlog planned at the beginning of the project can be found in Appendix C. If we had enough time we wanted to implement an advanced GUI for the project. This was not so important because we were mainly working with a proof-of-concept, but it would make the usability of the system better. Therefore we made this low priority. The system should also offer automatic notification by sms and email when errors occur. This was a small addition and was only considered a small priority.

5.4 Test Plan

This section presents the test plan for the testing of the implementations that were planned in the sprints.

5.4.1 The Testing Procedures

We decided that we were going to try to implement the system using a Test-Driven-Development model(3.3.1). But since we were inexperienced with the model, it would not be possible to implement the entire system using the TDD model. The TDD model would also make the coding more time-consuming for inexperienced users, which meant that we had to take some shortcuts to be able to finish in time. The unit tests are written using the JUnit framework.

We decided that we should also use a tool called Mockito(3.5) to make the system testable before the entire system was complete. Mockito offers the possibility to mock up Java classes that are yet to be implemented. This makes the testing of a half-implemented system easier.

Each component goes through four testing phases.

1. The component is tested using unit testing.
2. The component functionality is tested using black-box testing.
3. The component is integrated into a part of the system, and the interaction between the components is tested. Since the system has a clear distinction between front-end and back-end, they will be tested as two separate units before they are integrated.

4. The testing of the entire integrated system.

The black box tests have been produced during the sprints, and are a part of Appendix A.

The front-end is in considered to be the Datarec Database, the Web Service and the Web Page. The back-end is considered to be the ONSITE server, the Error Handler and the Datarec Database. The reason for testing the front-end and the back-end separate from each other is that the front and back-end can be working standalone and have no dependencies on each other. This makes it possible to start testing of the Web Service and Web Page early.

Due to the fact that we are developing the system purely as a proof of concept, the testing does not have to be as extensive as it would be for a system that is developed for actual use. This means that the customer will not be performing an acceptance test, since the customer's main interest in the result of our project is our experience with and recommendation of implementing the system.

Type	Description	Responsibility
Unit Test	Tests the low level code for expected output with unit tests. Helps to ensure that each part of the code works as expected.	Programmer
Integration Test	After completion of a module, it needs to be integrated with the rest of the system. After this procedure, the integration tests make sure the system works as it should.	Test leader
Functionality Test	Tests the functionality of the module against the requirement specification.	Test leader
Complete System Test	Tests all of the components integrated to work together as one.	Test leader

Table 5.9: Test Overview

5.4.2 Overall Schedule of the Testing

The project is implemented in the three sprints discussed above. The components that were finished in each sprint had to go through testing before they could be considered finished.

Sprint 1

By the end of Sprint 1 the following components had to be thoroughly tested:

- **Web Page:** The Web Page consists of three functionalities that have to be tested separately and together. These three are displaying unit information, displaying state logs for units, and marking error locations on a map.
- **Web Service:** The Web Service's communication with the database and the Web Page has to be tested.
- **Database:** It has to be tested whether storing and getting the data messages we operate with works as it should.
- **Datarec 7 SOAP Client:** The SOAP Client's communication with the Datarec 7 has to be tested.
- **Front End:** Since the entire front end is implemented during sprint 1, the integration of the front end should be tested.

Sprint 2

By the end of Sprint 2 the following components had to be thoroughly tested:

- **Error Handler:** Its communication with the database and the ONSITE server has to be tested, as well as its ability to recognize and convey errors.

Sprint 3

By the end of Sprint 3 the following components had to be thoroughly tested:

- **The ONSITE server:** The ONSITE server's communication with the Datarec 7 and the Error Handler has to be tested.
- **Complete System Test:** After all the components from the sprints have been integrated with each other, we have to test if they can work together as one.

6 Sprint 1

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The first sprint started in the fourth week of the project period, which was week 38. At the first sprint meeting we started the sprint planning. We soon realized that the product backlog had to be modified and slightly reorganized in order to get a clear sense of progress for each sprint. The first sprint was designed with the main focus of setting up and finishing the web service and the database. In addition to this, there should be put a substantial effort into making the SOAP interface continuously fetch data from the Datarec 7, and make the system detect errors. As sprint 1 was a week longer than other two planned sprints, we thought they should also put some effort into some of the lower prioritized items during the sprint. Thus we agreed that setting up the map service and making the web service display unit information and state logs for units should be finished during sprint 1.

6.1 Sprint 1: Sprint Goals

We found that it would be useful to identify a set of sprint goals for each sprint which they would aim to satisfy. As none of our team members had any previous experience working with agile development, a considerable goal was to successfully carry into effect the knowledge about Scrum that they had acquired through preliminary study and the Scrum lecture the 13th of September. This would mean implementing good routines for daily stand-up meetings and distributing tasks efficiently.

In addition to this we designed a sprint backlog specifically for sprint 1. This sprint backlog consisted of carefully chosen items from the product backlog that would form a basis for the subsequent sprints to build on. The main goals for sprint1 are to design, implement and test the web page, web service, the Datarec 7 connection client and the database. The web page, web service and the database part should be successfully presented to the costumer at Thursday the 13th of October 2011.

6.2 Sprint 1: Sprint Backlog

This section presents the backlog with documentation for sprint 1.

6.2.1 Sprint 1 Backlog Table

The numbers in the backlog table represents the number of hours that we have planned to spend on each item in the list.

ID	Task	Week 1					Week 2					Week 3					∑
		M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	
1	**Fetch data**																
	Design	10	10														20
	Test plan				5	5											10
	Code						8	8	8	4	4						32
	Test						2	2	2	1	1						8

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Table 6.1 – continued from previous page

ID	Task	Week 1					Week 2					Week 3					∑
		M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	
7	**Error Handler**																
	Design	10	15	20	5												50
	Test plan				5	10											15
2	**Database**																
	Schema			10													10
	Design							15	10								25
	Test plan								5	5							10
	Code									4	4			4	2		14
	Test									1	1			1	3	5	11
3	**Web service**																
	Design				10	10	5										25
	Test plan					5	10										15
	Code							5	8	8	8	8	8	8	5	5	58
	Test								2	2	2	2	2	2	10	10	32
4	**Map**																
	Design	10	5														15
	Test plan			8	2												10
	Code					10		10									20
	Test									5	5						10
5	**Unit info**																
	Design											10					10
	Test plan												5				5
	Code													10			10
	Test															5	5
14	**State logs**																
	Design											5	10				15

Continued on next page

Table 6.1 – continued from previous page

ID	Task	Week 1					Week 2					Week 3					∑
		M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	
	Test plan												5	5			10
	Code													5	15		20
	Test															5	5
	SUM	30	30	38	27	40	25	40	35	30	25	25	30	35	35	30	475

Table 6.1: Sprint 1 Backlog

6.2.2 Comments on the Sprint 1 Backlog

All of the implemented components goes through a four step cycle. The four phases is designing, the making of a test plan, implementation and testing. This model is closely related to the waterfall model, so that even though the project is based on scrum, the components are implemented with waterfall.

We decided to start the sprint with design of the data fetcher and error handler. The main reason for doing it in this order was that we wanted to know early what kind of error messages the system was able to catch and what kind of format they would have. Since our group consists of seven people, and not all of us were working on the data and error system, we also started with the map service during the first days of the sprint. When the design process was finished, we decided to start working on the Web service, which was the most extensive part of sprint 1. The web service is dependent on a working database, and the implementation of the database was therefore done in parallel with the web service. We decided to postpone the Unit information and state log part to the end of the sprint. This was due to the fact that the components were not crucial for the presentation of sprint 1.

6.3 Sprint 1: Main Deliverables

The deliverables for the first sprint was mainly to implement the web page, web service, database and Datarec 7 SOAP client. Because of the inaccessibility of the Datarec hardware, a mockup of Datarec 7 was created to simulate connection with the SOAP client. This answers the high priority requirements (Table 6.2) FR1 , FR2, FR13, FR14, FR15, FR16, FR17, FR18.

ID	Description	Priority
1. Continuously fetch data from Datarec7 installations		

ID	Description	Priority
FR1	The system should support the Datarec7 hardware	High
FR2	The system should use the SOAP interface to get the status of the Datarec7 hardware every second	High
2. Save data in database		
FR13	The system should use a SQL database to store the statuses and errors.	High
FR14	The system should convert the messages from the on-site server for database storage.	High
3. Set up web service		
FR15	The system should have a web service using SOAP.	High
FR16	The web service should use the SQL database to offer status and error data.	High
FR17	The web service should use the NorTraf database abstraction to get the coordinates of the roadside installations.	High
FR18	The web service should separate warnings and errors.	High

Table 6.2: High Priority Functional Requirements Sprint 1

The medium priority requirements FR19, FR20, FR24 were also fulfilled:

ID	Description	Priority
4. Show location of roadside installations on a map		
FR19	The system should use a map service to show the locations of the roadside installations on a map.	Medium
5. Display unit information		
FR20	The system should display the status of separate installations in a web page.	Medium
14. Display state logs for units		
FR24	The system should store the states of the separate installations in a database.	Medium

Table 6.3: Medium Priority Functional Requirements Sprint 1

6.4 Sprint 1: Design and Implementation

This section presents the design and implementation of the Datarec 7 SOAP Client, Datarec Database, Web Service and Web Page. It will also present the design of the Error Handler.

6.4.1 Datarec 7 SOAP Client

This is the part of the ONSITE server that is continuously fetching the status of the Datarec 7. Its only functionality is to use the SOAP interface of the Datarec 7 to get the status and store it as object classes, which are later sent to the error handler. The fetching of the status is executed as frequently as possible, to make the system as "real-time" as it can be.

The choice of IDE made the design and implementation of a SOAP client easy for us. In NetBeans you can just add a reference to a web service by pointing to its WSDL file, and NetBeans generates the required files and sets up a JAX-WS client automatically. The JAX-WS client lets us invoke the methods on the Datarec just as if they were on a local object. We decided not to include the automatically generated files in the class diagram to save space and avoid confusion. It is the *Dr7Communicator* class that handles the generating, sending and receiving of SOAP XML.

We decided that the best way to implement the SOAP client was to run it as a separate thread. This thread continuously fetches the status of the Datarec and updates a set of model classes. These model classes are monitored for changes by some other part of the ONSITE server, and are a part of a Model-view-controller pattern. The complete design of the Datarec 7 SOAP Client is presented in Appendix D: Design, section D.6.

6.4.2 Datarec Database

To store the statuses and error messages we decided to use a separate database. This database separates between statuses, error messages and warning messages. Since the only difference between error and warning messages is their type, we added a column where the type of the message is specified. The complete database scheme is presented in Appendix D: Design, section D.5.

6.4.3 Web Service

It was a requirement from the customer that the data gathered from the roadside installations was to be presented through a web service. The web service offers the statuses and errors from the database, and separates between resolved and unresolved errors. It also has the functionality to offer state and error logs, and the geographical location of the Datarec units. Information of the Datarec units, such as their geographical location, is obtained from the NorTraf database.

Another requirement was that all message passing should be XML, preferably SOAP XML, and for this reason we implemented the web service as a SOAP interface. Again, NetBeans made the task simple. By creating a web application and adding a web service,

all we had to do was declare the functions that were to be available through the SOAP interface. This is the *RequestHandler* class and it has four methods:

getUnresolvedErrors() This function returns an object containing a list of the unresolved errors and a list of their geographical location.

getRecentStatuses(int drId, int offset, int count) This function returns an object containing a list of the recent statuses of the specified Datarec unit and the Datarec unit's geographical location. The `offset` and `count` parameter is used to get subsets of the statuses. Setting `offset` to **0** and `count` to **1**, causes the method to return only the most recent status, while setting `count` to **-1** causes it to return all the statuses.

getRecentErrors(int drId, int offset, int count) This function returns an object containing a list of the recent errors of the specified Datarec unit and the Datarec unit's geographical location. The parameters works in the same fashion as described above.

getAllDataRecUnits() This function returns an object containing a list of all the Datarec units in the Nortraf database.

In order to increase portability of the web service, the support for different database drivers were added. The customer uses Oracle database, but since a MySQL database was more familiar and accessible we decided to create drivers for both Oracle and MySQL. In this way we could use MySQL while testing and the customer could set up the system to use their Oracle database. The complete design of the Web Service is presented in Appendix D: Design, section D.3.

6.4.4 Web Page

The customer requested that the data gathered from the roadside installations should be presented on a web page. The web page includes a map where the locations of the errors are marked. The web page also has the functionality to show state and error logs. The information required for implementing this functionality is given on demand from the Web Service.

The Web Service offers four methods to the Web Page, more information about them can be found in section 6.4.3. When the page is loaded, it uses these methods to get information about errors, warnings and locations. The customer required that the connection between the Web Page and the Web Service should communicate using XML(3.5), the connection was therefore implemented using SOAP-XML(3.5). Using NetBeans as the IDE made it easy to implement the SOAP Client, because the generated WSDL file from the Web Service makes NetBeans able to set up a JAX-WS client automatically. This makes the methods that the web service offer act as if they were on a local object.

The Web Page, including its logic, is implemented using Java(3.5), Java Server pages, JavaScript and HTML. It runs on a GlassFish server, which is a server-software from

Oracle implementing the Java6 Enterprise Edition platform. This makes it easy to hide some of the logic from the web page itself, and let the Web Page only handle the presentation. The map is implemented with map data from Statens Kartverk, as suggested by the customer. The map is presented using the OpenLayers library, which makes it easy to add maps to web pages, and also offers easy access to features like markers and zooming. The implementation design of the Web Page component can be found in Appendix D: Design, section D.2 and screenshots of the page can be found in section **??**.

6.4.5 Error Handler

The Error Handler had to consist of four parts. A part that:

- communicates with the ONSITE server – subscribing to status events and receiving status notifications.
- converts the incoming status notifications to a recognized format.
- detects errors.
- inserts statuses and errors into the database.

The customer wanted us to mimic an OPC server's behavior by mocking up a subset of its functionality. For this reason the part that communicates with the ONSITE server had to be an OPC client. At this point we did not know how to actually implement an OPC client, so we just added a class that would encapsulate the functionality of communicating with the OPC server. The implementation of the Error Handler was scheduled for sprint 2, hence we still had some time to figure out the details.

When the OPC client receives a status notification it uses a converter to transform the notification to a recognized format, before passing the notification to the error handler. The error handler uses several status checkers to determine if there are any errors, before inserting the status and possible errors into the database. The complete design of the Error Handler is presented in Appendix D: Design, section D.4.

6.5 Sprint 1: Testing

This section describes the testing of each of the components that were finished during Sprint 1. The components that were finished were the Datarec Database, the Web Service, the datafetcher from Datarec 7 and the Web Page. The Web Page, Web Service and the database were located at different computers at the time of the testing, to ensure that the system also is capable of working with the components being set up at different locations.

6.5.1 Web Page

While developing the Web Page, it was tested using Mockito to mock up the Web Service. It was needed to mock up the Web Service, since the Web Service was not created by the time we started implementing the Web Page. The testing of the Web Page differs a bit from the rest of the system, due to the fact that unit tests were not significantly used. This means that the testing had to be done more comprehensively, to ensure that the Web Page was error free. The fact that unit testing was not used significantly, made it crucial to find another way to test the smaller parts of the system. The testing of the Web Page was done by trying to make it fail, by giving it what was considered to be potential harmful input.

Input	Result	Comment
Select a unit	Passed	Worked properly
Jump to location	Passed	Worked properly
Open Datarec information of a unit not shown on the map	Passed	This test failed first time(NullPointerException) it was run, but passed after some debugging
Move map with mouse	Passed	Worked properly

Table 6.4: Tests Performed on the Web Page

During the testing, the test person found a NullPointerException error in the Web Page when referring to an ID which was not contained in the database. That needed to be fixed before the test could be retaken. The fixed Web Page passed the test, and was ready for module tests. The Web Page was supposed to fulfill the requirements that involved:

- Display unit information
- Show location of roadside installations on a map
- Display state logs for units

Therefore they had to be tested with T01, T02 and T03. The full description of the test can be found in appendix A.

Test Id	Result	Comment
T01	Passed	The test went without any irregularities. The test is passed because the expected output matches the real output. The Web Page was slow during the test with the system integrated.
T02	Passed	The Web Page behaved like it was supposed to. In this test the Web Page also was slow, but that is documented in T01
T03	Passed	The test went without any irregularities. The Web Page was slow during the test with the system integrated

Table 6.5: Web Page Test Cases

After the Web Page was accepted as a component, we integrated the Web Page with the database and the Web Service. Then it had to be tested if the integration had affected the behavior of the system, and all the tests needed to be redone. The tests confirmed that the integration had been successful. But the Web Page was rather slow after the integration. We suspected that this was because of the database, which was at that moment located at a rather slow connection in USA.

6.5.2 Web Service

The Web Service was developed using a TDD-model. This implies that the functions in the Web Service have been tested a lot.

This table contains module testing for the Web Service, that tests whether the Web Service fulfills its requirements. More detailed information about the tests can be found in the appendix A A.4.

Test Id	Result	Comment
T04	Passed	The coordinates were placed in our database, which means that the connection to the Nortraf database would not be tested in this test. This was due to the fact that we did not have access to the Nortraf database. But the system was successfully able to give the correct coordinates, and was considered successful.
T05	Passed	The tester was successfully able to set up a working connection between the Web Page and the Web Service using SOAP. The tests were carried out both by running the server and the client on one single computer, and by running them on separate computers. The test went without any irregularities, and was accepted.
T06	Passed	The system was able to get the status messages and the error messages successfully. This implies that the communication between the database and the Web Service worked appropriate, and the test was successful.
T07	Passed	The errors and warnings are separated in the database by a flag. The Web Service gets this flags and sets it "w" for warning and "e" for errors. The system was successful in this task, and it was possible to distinguish between errors and warnings.

Table 6.6: Web Service Test Cases

The Web Service has also been tested with extensive use; the Web Service was running during testing of the Web Page. Even though we were not looking for any specific problems, these tests thoroughly tested whether the Web Service contains errors that we did not plan for. During these tests, it was found that the Web Service handled the database being empty in a poor manner, and that had to be fixed.

6.5.3 Database

This section includes documentation of the testing process of the database. The database was mostly tested by simply using it. We never encountered any problems with the database we set up. The database was the first component we implemented fully, and there have been calls to the database since. The database is part of FR13 and FR14, and T08 found in Appendix A, is testing whether the database fulfills the requirements.

Test Id	Result	Comment
T08	Passed	The Database was working correctly. It is possible to store and get data from the database in the appropriate way. The test is therefore considered to be successful.

Table 6.7: Database Test Cases

6.5.4 Datarec 7 SOAP Client

This section includes documentation of the testing process of the SOAP client. The Datarec 7 SOAP is located at the ONSITE server and is the only part communicating directly with the Datarec 7. The client was developed using a TDD-model, and is therefore tested during development. At the early phases of the development, the Datarec 7 was mocked-up, because it was important to isolate the problems to being on the client itself. During testing of the component, it became clear that the Datarec 7 responds very slowly.

The Datarec 7 SOAP Client is part of FR1 and FR2 in the requirement specification. The following tests were applied to make sure that the requirements are fulfilled. A more detailed description of the test can be found in Appendix A.

Test Id	Result	Comment
T09	Passed	The system gets the right result from the Datarec 7, but the process of fetching data is a bit slow. The hardware uses 3-5 seconds when it responds to requests from the SOAP client. We think this happens because of the overhead that comes with using SOAP. The converting to XML and setting up HTTP takes some time, and the hardware in the Datarec 7 is slow. We considered the problem to be unsolvable, and therefore simply accepted the poor result.

Table 6.8: Datarec 7 SOAP Client Test Cases

6.5.5 Testing the Integration of the Database, the Web Service and the Web Page

This section describes the testing process involving the integration of the Datarec Database, the Web Service and the Web Page. From now, these components combined are referred

to as the front end.

The front end was tested in sprint 1, because it does not have any dependencies on the other parts of the system. The Web Service pulls the data from the Datarec Database on request from the Web Page. To test the front end, we integrated the three parts and prepared them to run as a system. Since changes in the database should cause the Web Page to change, we tested it by changing the information in the database, and checking how well the Web Page reacted to this. We tried this technique with various different inputs. At the end of sprint 1, the front end seemed to be working to satisfaction. At least from what we could tell, as we had to manually add input to the database, instead of getting it automatically from the implementations that would handle this job in the future. The front end would have to be tested in pair with the rest of the system in Sprint 3 before we could know for sure.

6.6 Sprint 1: Review

When this sprint started, we were a little afraid of coming further behind schedule. The reason for this was mainly due to the lacking man-hours we had up till that point. Over the three weeks the sprint lasted, we only got 25 hours behind schedule. This was estimated using a burndown chart. We thought this was a successful sprint, since we still had problems with reaching the estimated weekly hours and during the last week of the sprint only had 5 group members that worked.

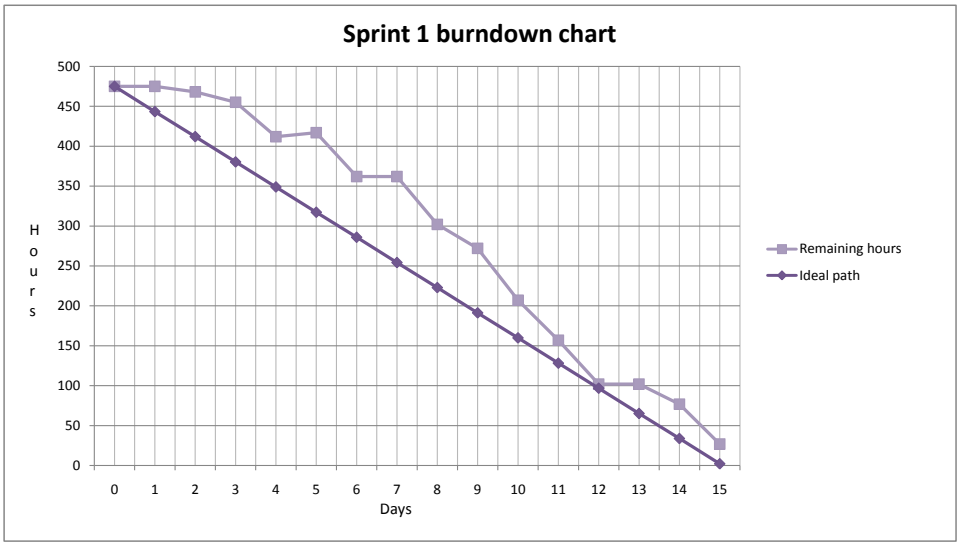

Figure 6.1: Sprint 1 Burndown Chart

As the burndown chart shows, the work started off at a slow start in sprint 1. During the last period of the sprint, the level of efficiency increased. This was partly because of a clearer delegation of tasks and members working from home. In this case, working from home improved our efficiency since less of the work time was used for idle chatting.
One of the reasons this burndown chart does not show a straighter line is that we try to avoid working in the weekends. On the end it was also partly affected by a delivery in another course for some of our group members.

6.6.1 Sprint 1: Positive Experiences

- Got close to everything done
- The implementation parts were done effectively

Even with our person-hours problem we got very close to everything done. That was good, since the hours lost would have to be placed into sprint 2.

6.6.2 Sprint 1: Negative Experiences

- Not very effective work on the report

- Should have delegated work better
- Some people did not participate as much as expected
- Lack of person-hours

The work on the report was slow and ineffective because the tasks that were focused on were to try to fill out parts already written. This is tedious work, and often leads to it being ineffective.
The delegation of work should have been better. And also the ability to come up with new tasks or sections to write about in the report. This would have made this sprint more effective and productive.
Some group members did not participate in the project as much as they should have. As the continuously low weekly man-hours suggest, we have a seemingly permanent problem with a couple of group members that are not working enough, and the last week of sprint 1 went by with five working members.

The lack of person-hours was our biggest problem in sprint 1. This increased the workload for other group members, and also brought with it some irritation. Other than that there were no big issues during the first sprint.

6.6.3 Sprint 1: Planned Actions

- A better delegation of work
- Delegate tasks to specialized group members

We realized that we had to be better at delegating tasks. We decided that we would find out what every group member is good at, and pick who does what based on that. Also, by improving our delegation of tasks, we hoped that the group members that did not work enough would start doing what they are supposed to if we would just force some work tasks on them. This would hopefully improve the efficiency of the group in general and lead to more work being done.

6.7 Sprint 1: Feedback

Friday October 14th we presented the results from sprint 1 for the customer. The customer representative on this meeting was Jo Skjermo, the usual representative.

At the meeting, the customer representative expressed that the project so far looked good. He had some feedback for the Web Page and the graphical user interface there. He wanted to introduce different frames to the user interface. The reason for these different frames was to make the map's position static, while the information about the Datarec

unit can be scrolled through at will. Other than that the customer representative came with some suggestions on how to make the errors easier to recognize and make it easier to read the information.

7 Sprint 2

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The second sprint phase in the Scrum period started in week 41, and was planned to last for two weeks. During sprint 1 we had implemented functionality for saving data in a database, continuously fetching data from the Datarec 7, showing location on a map service, and displaying unit information and state logs for said units. In addition to this we had finished setting up the web service. In other words, all the planned items from the sprint 1 backlog had been successfully implemented, except for the "Detect errors"-item. Consequently, this item was carried over to sprint 2.

7.1 Sprint 2: Sprint Goals

The main goals for sprint 2 were to implement most of the error handler and the on-site server. When the sprint started we thought we were going to implement an OPC server, but midway into the sprint, we had to change some requirements, and our sprint goal became to implement most of the ONSITE server instead. Since sprint 1 was not quite done, some parts had to be moved into the start of sprint 2. The new plan was to finish the part from sprint 1 as fast as possible.

We predicted that the ONSITE server and error handler would be very time consuming, especially the server. That is reflected through the fact that we have allocated more time to the implementation of the server than the error handler.

7.2 Sprint 2: Sprint Backlog

This section presents the backlog with documentation for sprint 2.

7.2.1 Sprint 2 Backlog Table

The numbers in the backlog table represents person hours that we have planned to spend on each item in the list.

Story ID	Story / Task	Week 1					Week 2				
		M	T	W	T	F	M	T	W	T	F
11	**On-site server**										
	Design	20	20	20							
	Test plan			10	5						
	Code				9	8	17	17	16	9	
	Test				1	2	3	3	4	1	
11	**Error handler**										
	Code	12	7	5	15	21	7	12	7	15	23
	Test	3	1	0	5	4	1	3	1	3	5
	SUM	35	28	35	35	35	28	35	28	28	28

Table 7.1: Sprint 2 Backlog

7.2.2 Comments on the Sprint 2 Backlog Table

The ONSITE server is the most extensive part of the whole project. And it is also the main goal for this sprint, even though we did not plan to finalize it in this sprint. The reason for putting 60 hours into the design of the ONSITE server, is that the server should offer some advanced features and therefore needs a carefully chosen design to work appropriately. The Error Handler and the ONSITE server should communicate with each other, and this feature was planned to be implemented by the first week.

7.3 Sprint 2: Main Deliverables

The main deliverable for sprint 2 was the implementation of the Error Handler. More explicitly, the deliverable parts of the Error Handler were to make it able to receive error

messages from the on-site servers, get a list of all the roadside installations from the NorTraf database and create warnings on errors and distinctive data. table 7.2 shows the functional requirements (FR7, FR8, FR9, FR10, FR11 and FR12) this implementation fulfilled.

ID	Description	Priority
12. Set up the Error handler		
FR7	The Error Handler should be able to receive messages from the on-site servers.	High
FR8	The Error Handler should be able to register itself as a listener to the on-site servers .	High
FR9	The Error Handler should get a list of all the roadside installations and their IP addresses from the NorTraf database abstraction level.	High
FR10	The system should use the data from on-site server to detect peculiar data, loop failures, hardware errors or wrong hard-wiring.	High
FR11	The errors should be separated from the regular data messages.	High
FR12	The Error Handler should create warnings on irregularities and peculiar data.	High

Table 7.2: Functional Requirements Sprint 2

7.4 Sprint 2: Design and Implementation

This section presents the design and implementation of the ONSITE Server and Error Handler.

7.4.1 ONSITE Server

For the implementation we decided to go with GlassFish server, a server-software from Oracle implementing the Java6 Enterprise Edition platform, and normal java desktop programs running on the same computer. The server runs the web service used for communicating over SOAP. This allows us to handle SOAP-calls fairly transparently, enabling us to use SOAP-calls like normal Java methods. The downside of using a server like GlassFish is that web services lack a main method like Java desktop applications have. This meant that we could not have a loop continuously pulling data from the Datarec hardware, which the customer required. To get around this we made a normal desktop application running a loop that pulls statuses from the hardware, then calls a SOAP-method for every client that is registered with the server. Clients register through the Web Service, which then sends the info needed to the desktop application through sockets. The complete design of the ONSITE server is presented in Appendix D: Design,

section D.6

7.4.2 Error Handler

The schedule for sprint 2 was to implement the design created in sprint 1, but after some suggestions of changes from the customer, we redesigned parts of the Error Handler. The new design was more complex than the initial design, but the new suggestions can only be partly blamed for this. While redesigning, we added parts that were thought to make the Error Handler more useful.

What we called *OpcClient* in the initial design is now separated into two parts:

Subscriber is a JAX-WS SOAP client that handles the subscribing to and unsubscribing from status events on the ONSITE servers.

ErrorHandlerService is a JAX-WS web service that is used to receive status notifications from the ONSITE servers. When it receives a notification it uses the converter to transform the notification into a recognized format, before sending the notification to the Error Handler through a local socket connection.

The reason we did this is that we needed to mimic an OPC server's ability to push notifications, and since the customer wanted us to use SOAP XML as message passing we decided to use web services. While a web service would solve the task of receiving status notifications, checking for errors and inserting them into the database, it would not be able to subscribe to the events. At this point we had decided that it would be best if the user of the system could manually specify which units to subscribe to, and for this we needed a GUI.

The Error Handler is now a standalone application with a GUI. It has a SOAP client that handles subscribing to events, and a socket server that listens for incoming connections from which to receive status notifications from the Error Handler Service. In order to list all the available Datarec units to subscribe to, we had to create a database connection to the NorTraf database. While doing this, we decided to adapt the support for different database drivers, as we did with the Web Service implemented in sprint 1.

The complete design of the Error Handler and *ErrorHandlerService* is presented in Appendix D: Design, section D.4.

7.5 Sprint 2: Testing

The Error Handler was the only component which was supposed to be finalized during sprint 2. Even though the test plan for the ONSITE server was constructed during sprint

2, the documentation of the testing is included in the testing chapter in sprint 3 (section 8.5).

7.5.1 Error Handler

It was initially planned to test the Error Handler during sprint 2. But due to delays in the implementations, the actual testing was not completed before sprint 3. The Error Handler was developed using the TDD technique, which means that it had gone through testing during the development phase. The Error Handler had three major parts that needed testing; the connection to the ONSITE servers, the detection of errors and inserting errors and warnings into the database. These features correspond to the requirement identified in chapter 4.

T10,T11 and T12 tested these features. The tests can be found in Appendix A.

Test Id	Result	Comment
T10	Passed	The setup with the ONSITE server worked satisfactorily, and the connection was successfully set up. The Error Handler successfully received the message from the ONSITE server. The testing of whether the Error Handler was able to get the IP address from the NorTraf database was hard to check in a satisfactory way, because the database we got from the costumer only had telephone numbers stored. We added the IP address manually to make it possible to test, and then it was successful. Another issue is that we did not have access to the real NorTraf database during the project, so the costumer needs to test this feature themselves with access to the database. The error handler is equipped with Oracle drivers (the NorTraf database is an Oracle database), so this should be working properly. Since this feature was fully functional on our prototype, it should be working on their system as well, and is therefore considered successful.
T11	Passed	The error handler successfully recognized the errors and added them into the database. The test is therefore considered successful.
T12	Passed	After the test was completed, the only data that was added in the database was the error and warning messages. This implies that the test was successful, and had passed. The error handler shows the correct behavior.

Table 7.3: Error Handler Test Cases

7.6 Sprint 2: Review

At the start of second sprint, we were in quite good spirits, even with the problems we had with lazy evasive group members and the slight lag in schedule. Sprint 2 did not go quite as smoothly as we had hoped, however. At the end of week 41, which was the first week of the sprint, the group and the customer came to the conclusion that a major requirement had to be changed. The server that was to run on the on-site laptop was supposed to be using OPC. Sadly OPC could not push, which mean that we had to figure out something else. This was a major set back.

Because of this, we would need to have a server and a client on each side, both in the ONSITE server and at the Error Handler. This meant that the requirements would take longer to implement than planned, and resulted in an even more delayed finish of the second sprint.

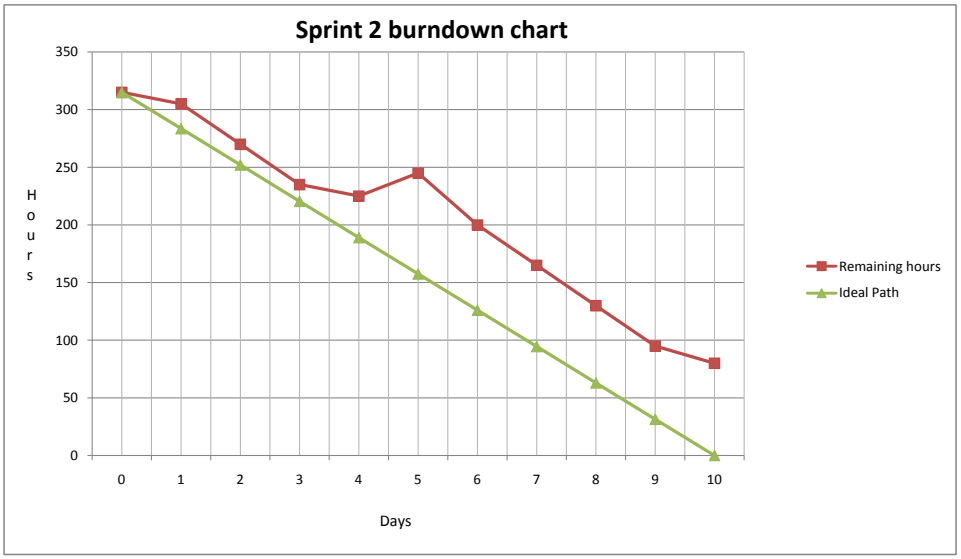

Figure 7.1: Sprint 2 Burndown Chart

As the burndown chart shows, the level of efficiency was good. Due to the OPC and server problems, and the major setback, we got about 80 hours behind schedule. Hopefully this will be finished during the first week of sprint 3, but will probably make it necessary to drop some of the lesser requirements for the system.

7.6.1 Sprint 2: Positive Experiences

- More commitment from certain group members
- The delegation of tasks was better during this sprint
- The daily Scrum meetings
- Customer happy with Sprint 1
- The amount of person hours have increased

The persons that have not worked enough earlier are now starting to contribute a bit more. This means that the group at last is starting to get closer to the estimated amount of person hours each week.

A better delegation of tasks, together with more hours, made this a more successful sprint in form of management.

The daily Scrum meetings started to pay off. We got a better overview of what was being done, what needed to be done and the rate of work done. It was also helpful in delegation of work and setting deadlines.

The customer seemed happy with what had been done in sprint 1. He had some feedback, but was overall happy with the result.

The amount of person hours increased during the second sprint. The last week we combined worked for 145 hours, which is much better than what has been done previously.

7.6.2 Sprint 2: Negative Experiences

- Still struggling with reaching estimated person hours
- The first week - low amount of person hours
- Trouble with the OPC

The estimated amount is still out of our reach, even though we are getting closer.

The first week had a low amount of person hours. With under 100 hours worked, we lacked nearly half the estimated workload. The reasons for this was that some of the students did not put in enough work, and several students were ill.

We could not use the OPC standard quite as planned. Instead we had to make our own kind of server which mimics the OPC standard. The reason for this was that OPC is unable to push data. This set us back a bit, and made the sprint harder and more time consuming.

7.6.3 Sprint 2: Planned Actions

- Even better at task delegation
- Increase the total amount of hours worked even more

There is always room for improvement, and this group is no different. With a better and more even delegation of tasks, the progress should get better and more steady. There is also room for improvement with regard to the hours worked each week. Our hope is to get everyone at least over 20 hours for the next week. This should also increase the amount of actual work done, which makes us able to catch up a bit to the plan.

7.7 Sprint 2: Feedback

The first customer meeting after the sprint 2 period was Friday 28th of October. Consequently this was the meeting where we presented the implementations from sprint 2 for customer representative Jo Skjermo.

Due to the changes in the requirements that happened midway through the sprint, we did not quite manage to finish the implementations that we had planned for. The separate parts of the system were all finished, but they had not yet been integrated with each other. It had turned out to be slightly harder than expected. We explained how the servers and clients would communicate with each other, and the customer was very understanding of the situation that we were in, and seemed content with what he was shown. It was agreed that we would present the complete ONSITE server/client and Error Handler implementations a week later.

8 Sprint 3

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The third and last sprint phase in the project period started in week 43. The planned duration for this sprint was two weeks. Sprint 2 was designated to make the on-site server and client. The second sprint was, due to some complications, behind schedule. This made us skip some of the lesser requirements for sprint 3 to be sure we would finish the most important parts of the project in time. The requirements that in the revised plan were to be done in sprint 3 were the ONSITE server and client, installation guide, design of web interface and the automatic notification by sms and mail.

8.1 Sprint 3: Goals

The main goals for sprint 3 were to finish the implementation of the ONSITE server and client, which is the most important part of our system implementation. The installation guide, the web interface design and the automatic notification comes in addition to this.

With the problems in sprint 2, the server and client part turned out to be very time consuming. This can also be seen in the backlog, where the server and error handler, which is a part of the client, has been prioritized with about 55 percent of the allocated time in the backlog.

8.2 Sprint 3: Sprint Backlog

This section presents the backlog with documentation for sprint three.

8.2.1 Sprint 3 Backlog Table

The numbers in the backlog table represents person hours that we have planned to spend on each item in the list.

Story ID	Story / Task	Week 1					Week 2				
		M	T	W	T	F	M	T	W	T	F
11	**Set up the ONSITE server**										
	Code	12	12	12	12	25	25				
	Test	3	3	3	3	5	5	30			
	Error Handler										
	Code	12	12	10							
	Test	3	3	5	15						
13	**Create installation guide**										
	Write								20	20	
9	**Design web interface**										
	Design								10		
	Code								5		
	Test								5		
6	**Automatic notification**										
	Design									5	
	Code									13	20
	Test									2	5
	SUM	30	30	30	30	30	30	30	40	40	25

Table 8.1: Sprint 3 Backlog

8.2.2 Comments on the Sprint 3 Backlog Table

The server is again the main part. This is due to its importance in the overall function of the prototype. The second most important part of the third sprint is the creation of the installation guide, since this will take some time. The design of web interface and

the automatic notification is something that can be done quite quickly, so they are not heavily prioritized.

8.3 Sprint 3: Main Deliverables

The deliverables for this sprint is the finished prototype, meaning all the components had to work together. To make this work, the developers finished the ONSITE server. With this finished, functional requirements FR3, FR4 and FR5 were fulfilled. See table 8.2 for reference to these requirements.

ID	Description	Priority
11. Set up the on-site server		
FR3	The server on-site should mimic a subset of the OPC functionality	High
FR4	The server on-site should be able to register listeners.	High
FR5	The server on-site should be able to push data.	High

Table 8.2: Functional Requirements for the ONSITE Server

8.4 Sprint 3: Design and Implementation

The design for both ONSITE server and Error Handler was finished in sprint 2, so sprint 3 was dedicated to carry out the rest of the implementation and testing.

8.5 Sprint 3: Testing

This chapter explains the testing done during sprint 3. The ONSITE server was finished during sprint 3, and needed extensive testing. In the end of this sprint, the whole system was finished, which means that we had to integrate all parts of the system to check if it worked together as a unit.

8.5.1 ONSITE Server

The final testing of the ONSITE server was done in the last week of sprint 3. The ONSITE server is the server that connects to the Error Handler, and automatically forwards messages from the Datarec 7. The most important part that needed testing was to make sure that the system was able to push messages, and that the ONSITE server could establish a connection to the Error Handler.

T13 involves the ONSITE server, T13 can be found in Appendix A.

Test Id	Result	Comment
T13	Passed	The reason for using a mocked up Datarec 7 SOAP client instead of a real Datarec 7, is that we had no way to produce the error at the Datarec 7 location. The test went without problems, the connection to the Error Handler was successfully established and the pushing was working satisfactorily. This also suggests that the Error Handlers part is working according to plan. The test was considered successful.

Table 8.3: ONSITE Server Test Cases

8.5.2 Complete System Test

This section describes the testing that was performed when the entire system was finished.

The testing of the system was delayed to after sprint 3, because of the delays in the implementation. When the testing was supposed to be performed, the connection to the roadside hardware failed. Therefore we had to go and get the roadside installation from its location, and place it on the graphics lab at NTNU. This happened in the last week of the project, which meant that the system did not have much time to be completely tested. The Database, Web Service and Web Page were tested together in sprint 1, but the testing of the integration of the system had been limited.

During the time the connection to the roadside hardware was unavailable, some limited testing was done using a mock up that included a simulation of multiple roadside hardware, and using a black-box test where the user was using the Web Page and the Error Handler GUI. The mock-up produced status messages every 10 seconds, with a 25% probability of the status to be an error. This led to the discovery of some problems with the integration of the system, but the problems were all successfully fixed.

Ideally, the testing should have been performed with multiple real pieces of hardware (that were actually installed roadside), with the possibility to produce errors by for instance pulling out the cables of the hardware. But due to the problems that occurred, we did not have time for a proper final testing. This means that the prototype developed may not be completely faultless.

8.6 Sprint 3: Review

The third, and last, sprint contained the rest of the second sprint, and some lesser requirements. The ONSITE server, which was what did not get completed in sprint 2, was the most important part of the third sprint. The lesser requirements that were included in sprint 3:

- Design web interface
- Create installation guide
- Automatic notification

Due to the delay from sprint 2, some of the lesser requirements were not included in the backlog for sprint 3.

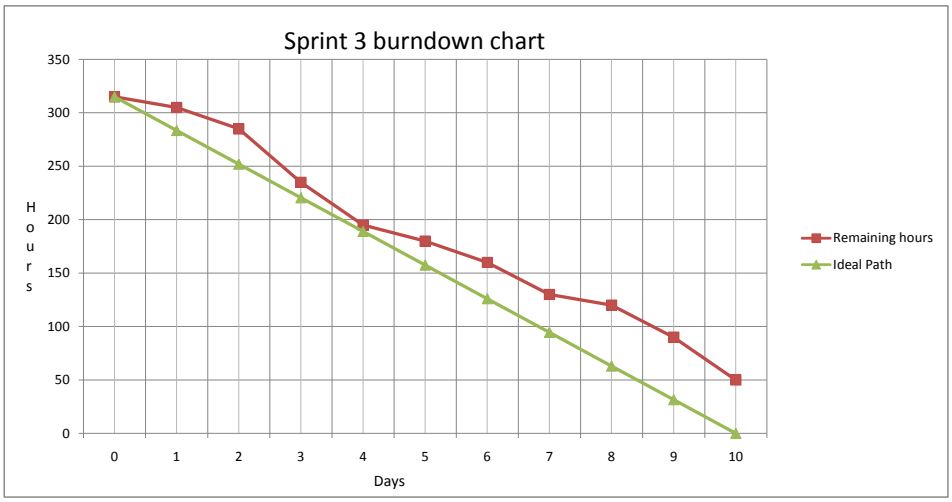

Figure 8.1: Sprint 3 Burndown Chart

As the burndown chart shows, the sprint was a bit behind schedule. When this sprint was at an end, it was closer to the plan than the second sprint. Due to the ONSITE server we had to skip some lesser requirements, and that includes the Automatic notification, which was in the sprint backlog. Since the Automatic notification and installation guide was not

completed, the sprint ended with about 50 hours left. The installation guide is something that will have to be done during the last two weeks before the presentation.

8.6.1 Sprint 3: Positive Experiences

- Specific deadlines
- Better delegation
- Delegated chapters
- Increase of work hours

We have started with specific deadlines for all tasks. This made it easier to see the progression of the work and also put pressure on the students that have not involved themselves in the project. Due to this, the effect is that the efficiency of the work is increased a bit.

The delegation has been improved again. It is partly due to the deadlines, which makes it easier to assess when someone would need new work and have finished their tasks.

We started to delegate chapters in the report, to have people that are responsible to control the overall flow of the chapter and check the correctness of the text written.

There was an increase in the total work hours.

8.6.2 Sprint 3: Negative Experiences

- Replanning of sprint 3
- The implementation of the ONSITE server
- Fake hours
- Leftovers
- Customer presentation
- OPC problems - no push
- Wrong priorities

We had to replan the third sprint due to the delays in the server-client part of sprint 2.

The ONSITE server took much more time than expected.

From the work done and the hours written, and explained in mail, there seems to be quite a few “fake” person hours.

There were some leftovers from this sprint. This includes Oracle database drivers for the Web Service, timeout error check, installation guide and to bundle stuff together.

Sadly the presentation for the customer was not as it should have been, due to the fact that we had to use a mock-up of the Datarec and that the computer which was showing the web page was partially damaged.

As explained in the sprint 2 chapter, the OPC did not have the ability to push. Therefore we decided to make a server and client on both sides. This set us back quite a bit, and lead to the third sprint having to cover work tasks that were planned for the second sprint.

There are still a couple of students in our group that are not involving themselves enough in our project. This affects the group as a whole. It affects both our team spirit and increases the workload for the rest of the group.

8.6.3 Sprint 3: Planned Actions

This is the last sprint, so the planned actions are for the last weeks of the project and good ideas to take to other projects.

- Continue with deadlines
- Continue to increase hours worked
- Increase productivity in the report

Since the deadlines have had such a good effect, we are going to continue with this.

As the project is getting closer to the end, and there is still a lot to do, the amount of hours will have to increase even more.

At this point in our project process we decided to make a new "chapter delegation system" that is further described in section 2.4.5. We hope to increase the productivity in the report writing, since certain parts of our report is still quite lacking.

8.7 Sprint 3: Feedback

The customer was very understanding when the reason for the delays and missing requirements was explained. He seemed to be satisfied with what he was shown. The customer were shown the system working with a mock-up of the Datarec. The design of the Web Page was also shown, but due to a partly damaged screen on the laptop that we used to show the Web Page to the customer, it was not easy for him to see anything. We promised the customer that for the next meeting, we would show him the Web Page on a computer with a working screen.

9 User Guide

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In this section the installation and use of each part of the system is presented. The delivered system has installation scripts for all the separate parts.

9.1 ONSITE Server

In this section the installation and use of the ONSITE server is presented.

9.1.1 Installation

The ONSITE server consists of two parts:

DrRegisterNotifications is a web service that handles subscription requests. It uses GlassFish as application server, so it requires that GlassFish and Java EE is preinstalled. The install script also requires that the Java/bin directory is placed in the `PATH` environment variable.

DrNotificationPusher is a standalone Java application that receives subscription requests from *DrRegisterNotifications* while continuously fetching the status from the Datarec unit and pushing notifications of changes to the subscribers. The *DrNotificationPusher* requires that Java is preinstalled.

Both these parts are configured and installed by running the belonging install script `setup.bat`. The scripts needs to be run as Administrator to be able to complete the setup.

During the setup the user has to enter the installation directory of GlassFish, domain name and instance port number of the GlassFish instance and the port number to use to forward subscription requests from *DrRegisterNotifications* to *DrNotificationPusher*. The reason for having to specify the port number of the local socket connection is to ensure that it is not used by another application.

The two parts also has a configuration file. This configuration file specifies the port number to use when forwarding subscription requests and which events that can be subscribed to. The configuration file is automatically created while installing, but can be altered at any time later to change the settings of the ONSITE server. A reboot is required to apply the changes.

```
# ONSITE Server config

port = 11111
events = UNIT_STATUS_CHANGED_EVENT
```

Listing 9.1: Example - Configuration file for the ONSITE server

After the setup is complete, an uninstall script is created. This can be used to remove the installed system. The uninstall scripts needs to be run as Administrator to be able to remove all the parts of the system.

9.1.2 Usage

After installing, the ONSITE server runs on its own. There is no need for further interaction with it. Just make sure that it is running and that the router is properly configured to allow access to the *DrRegisterNotifications* web service.

9.2 Error Handler

In this section the installation and use of the Error Handler is presented.

9.2.1 Installation

The Error Handler consists of two parts:

ErrorHandlerService is a web service that receives status notifications from the ONSITE servers. It uses GlassFish as application server, so it requires that GlassFish and Java EE is preinstalled. The install script also requires that the Java/bin directory is placed in the `PATH` environment variable.

ErrorHandler is a standalone java application that receives status notifications from the *ErrorHandlerService*, checks if there are any errors and inserts the statuses and possible errors into the *Datarec* database. It also has the functionality to subscribe to and unsubscribe from status events on Datarec units. The *DrNotificationPusher* requires that the Java runtime is preinstalled.

Both of these parts are configured and installed by running the belonging install script `setup.bat`. The script needs to be run as Administrator to be able to complete the setup. During the setup the user has to enter the installation directory of GlassFish, domain name and instance port number of the GlassFish instance and the port number to use to forward status notifications from the *ErrorHandlerService* to the *ErrorHandler*. The user also has to enter the configurations of both the *Datarec* and *Nortraf* database.

During the setup, two configuration files are generated. These configuration files contain the information entered by the user, and can be used to change the settings of the Error Handler at any time. A reboot is required to apply the changes.

```
#ErrorHandlerService Config
errorHandlerHost=localhost
errorHandlerPort=44446
```

Listing 9.2: Example - Configuration file for the ErrorHandlerService

The configuration file of the *ErrorHandlerService* consists of the host name / IP and port number of the *ErrorHandler*.

```
#ErrorHandler Config
dr_databaseHost=localhost
dr_databasePassword=password
dr_databasePort=3306
dr_databaseService=datarec
dr_databaseSoftware=MYSQL
dr_databaseUser=username
nt_databaseHost=localhost
nt_databasePassword=password
nt_databasePort=1521
nt_databaseService=nortraf
nt_databaseSoftware=ORACLE
nt_databaseUser=username
localPort=44446
servicePort=44444
subscriptionTimeout=600
minBatteryVoltage=10000
```

Listing 9.3: Example - Configuration file for the ErrorHandler

The configuration file for the *ErrorHandler* consists of:

- the configuration of the *Datarec* database
- the configuration of the *Nortraf* database
- the port number it should listen for incoming status notifications (*localPort*)
- the port number of the *ErrorHandlerService*
- the time number of seconds before a subscription is marked as "timed out"
- the minimum battery voltage before an error is triggered

After the setup is complete, an uninstall script is created. This can be used to remove the installed system. The uninstall scripts needs to be run as Administrator to be able to remove all the parts of the system.

9.2.2 Usage

After the installation is complete, a GUI will appear. This is the Error Handler, and it has to run for the system to be able to detect errors and store errors and statuses in the database.

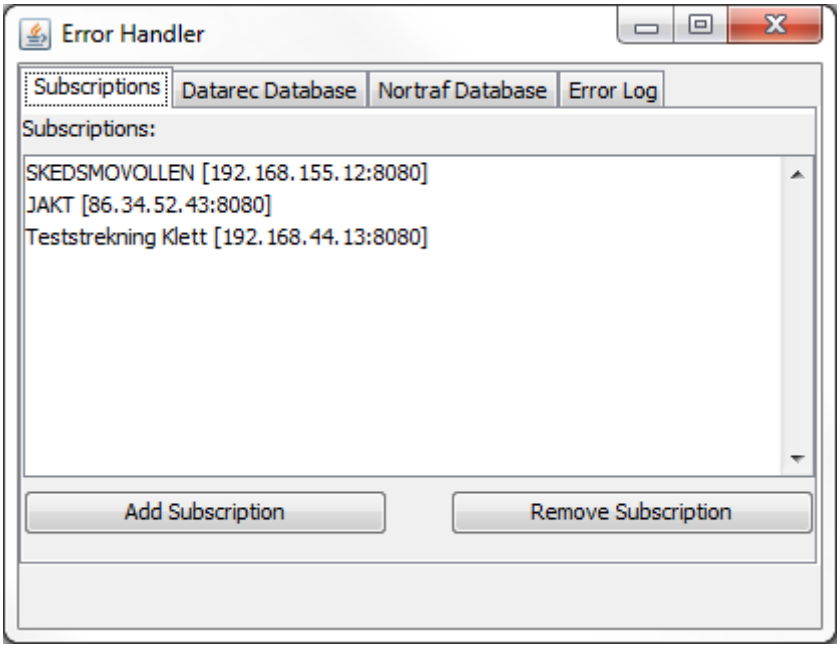


Figure 9.1: Error Handler - Subscriptions

The GUI is tab based, and the first tab contains the list of subscriptions. Here you can add and remove subscriptions. Clicking "Add Subscription" brings up a dialog.

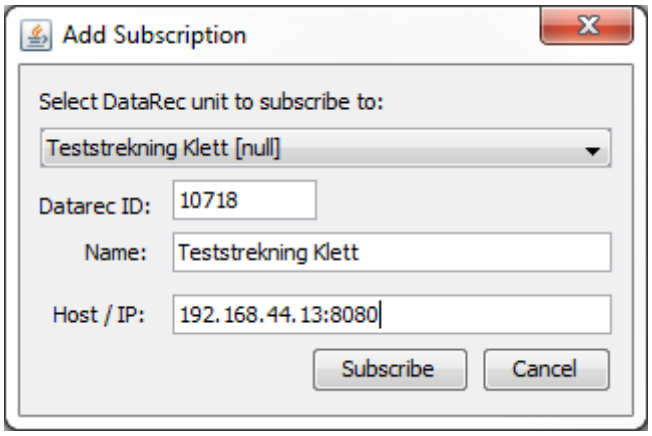


Figure 9.2: Error Handler - Add Subscription

When opening this dialog, the Error Handler populates a drop down menu with all the Datarecs available in the *Nortraf* database. If the Datarec unit you want to subscribe to is not in the list, you can choose to create a custom subscription. The only thing is that you have to specify the Datarec ID of a Datarec unit that is in the database, otherwise the *Web Service* will not be able to map the statuses and errors to a Datarec unit.

The Error Handler fetches the IP of the router, that the Datarec is connected to, from the *Nortraf* database. If the IP is not present, you need to specify a host name or IP address before subscribing. You also have to specify the port number of the *DrRegister-Notifications* service as shown in figure 9.2, if it uses any other than the default HTTP port `80`.

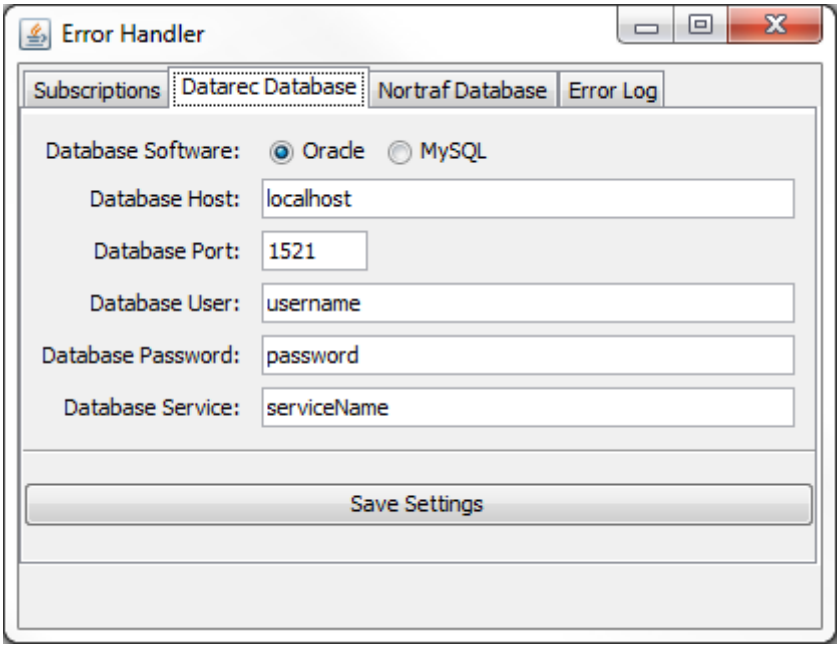


Figure 9.3: Error Handler - Database Configuration

The next two tabs are for modifying the configuration of the databases. You can modify all the different fields. After modifying the configuration, you have to click "Save Settings" to save the settings.

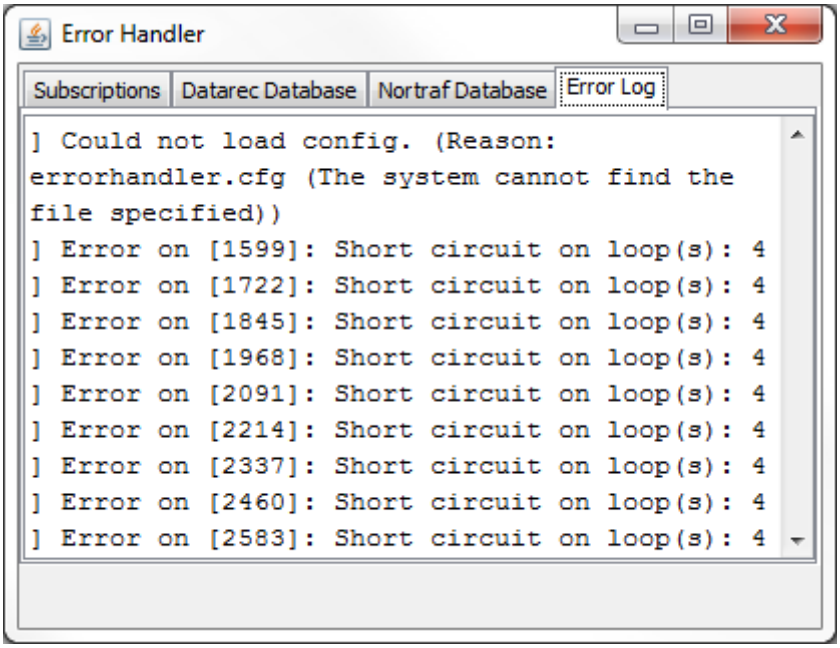

Error Handler
Subscriptions
Datarec Database
Nortraf Database
Error Log
] Could not load config. (Reason:
errorhandler.cfg (The system cannot find the
file specified))
] Error on [1599]: Short circuit on loop(s): 4
] Error on [1722]: Short circuit on loop(s): 4
] Error on [1845]: Short circuit on loop(s): 4
] Error on [1968]: Short circuit on loop(s): 4
] Error on [2091]: Short circuit on loop(s): 4
] Error on [2214]: Short circuit on loop(s): 4
] Error on [2337]: Short circuit on loop(s): 4
] Error on [2460]: Short circuit on loop(s): 4
] Error on [2583]: Short circuit on loop(s): 4

Figure 9.4: Error Handler - Error Log

The last tab contains a text area. This text area contains detected errors and exception messages if any exceptions are caught. If the error log contains exception messages, it means that something has gone wrong while checking for errors and inserting them into the database. The error has to be fixed for the Error Handler to be working properly.

9.3 Web Service

In this section the installation and use of the Web Service is presented.

9.3.1 Installation

The Web Service uses GlassFish as application server, so it requires that Java EE and GlassFish is preinstalled.

Installing the Web Service is done by running its install script `setup.bat`. The script needs to be run as Administrator to be able to complete the setup. During the setup the user has to enter the installation directory of GlassFish, domain name and instance port

number of the GlassFish instance and the configuration of both the *Datarec* and *Nortraf* database.

During the setup, a configuration file is generated. This configuration file contains the configuration of both the *Datarec* and *Nortraf* database, and can be modified at any time to change the settings of the Web Service. A reboot is required to apply the changes.

```
#Web Service Config
dr_databaseHost=localhost
dr_databasePassword=password
dr_databasePort=3306
dr_databaseService=datarec
dr_databaseSoftware=MYSQL
dr_databaseUser=username
nt_databaseHost=localhost
nt_databasePassword=password
nt_databasePort=1521
nt_databaseService=nortraf
nt_databaseSoftware=ORACLE
nt_databaseUser=username
```

Listing 9.4: Example - Configuration file for the Web Service

After the setup is complete, an uninstall script is created. This can be used to remove the installed system. The uninstall scripts needs to be run as Administrator to be able to remove all the parts of the system.

9.3.2 Usage

After installing, the Web Service runs on its own. There is no need for further interaction with it. Just make sure that it is running and that the router is properly configured to allow access to it.

9.4 Web Page

In this section the installation and use of the Web Page is presented.

9.4.1 Installation

The Web Page uses GlassFish as application server, so it requires that Java EE and GlassFish is pre-installed.

Installing the Web Page is done by running its install script `setup.bat`. The script needs to be run as Administrator to be able to complete the setup. During the setup the user has to enter the installation directory of GlassFish, domain name and instance port number of the GlassFish instance, as well as the host name / IP and port number of the Web Service from which it gets its data.

During the setup, a configuration file is generated. This configuration file contains the host name / IP and port number of the Web Service, and can be modified at any time to change the settings of the Web Page. A reboot is required to apply the changes.

```
#Web Page Config
host=localhost
port=44445
```

Listing 9.5: Example - Configuration file for the Web Page

After the setup is complete, an uninstall script is created. This can be used to remove the installed system. The uninstall scripts needs to be run as Administrator to be able to remove every part of the Web Page from your system.

9.4.2 Usage of the Web Page

After the installation is complete, the Web Page is deployed on the GlassFish server it was installed on. The site will then be possible to access from http://[IP]:[Port]/WebPage. The Web Page is responsible for the presentation of the error data stored in the Datarec error database.

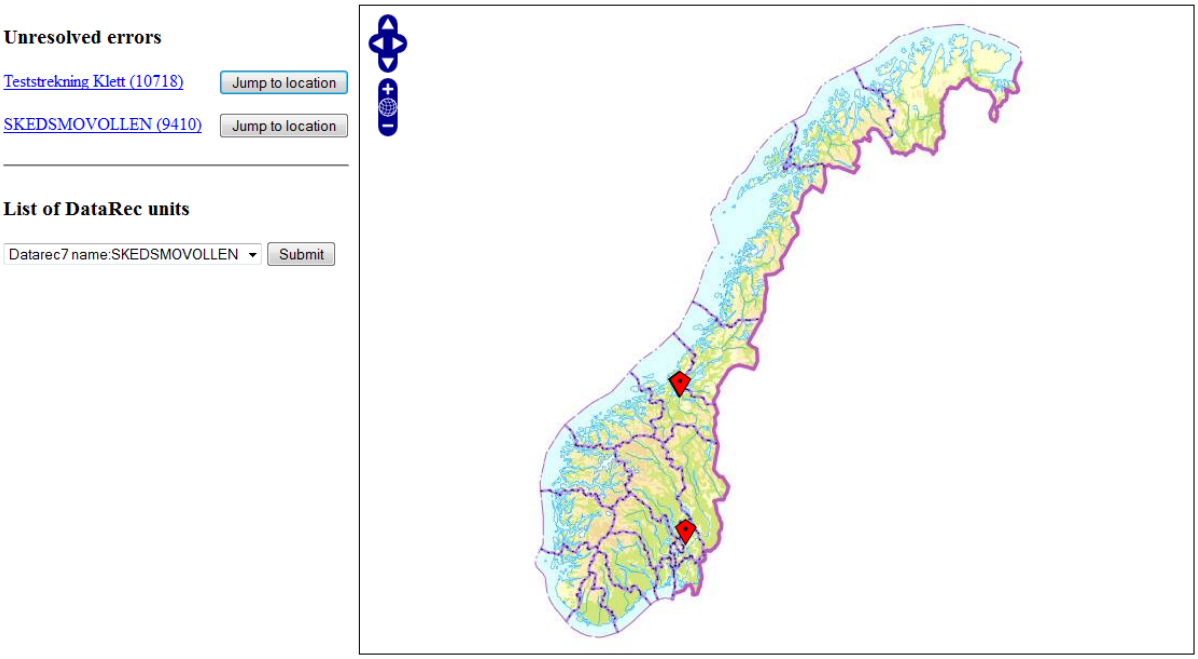


Figure 9.5: Web Page - Front Page

The site contains a map that displays the roadside installations with a marker. The marker should be marked red if there is an error on the roadside installation, yellow if there is a warning and green if the roadside installation is running appropriately. When the "jump to location" button is clicked, the map should move to a local view, where the marker is placed.

When the user clicks on the marker or the name of the Datarec under the "Unresolved errors" list, the page opens the unit status page for the Datarec. If the user wants information about a Datarec which does not have an error, it is possible to get to the unit status page by using the drop down list, called "List of DataRec units", and press submit.

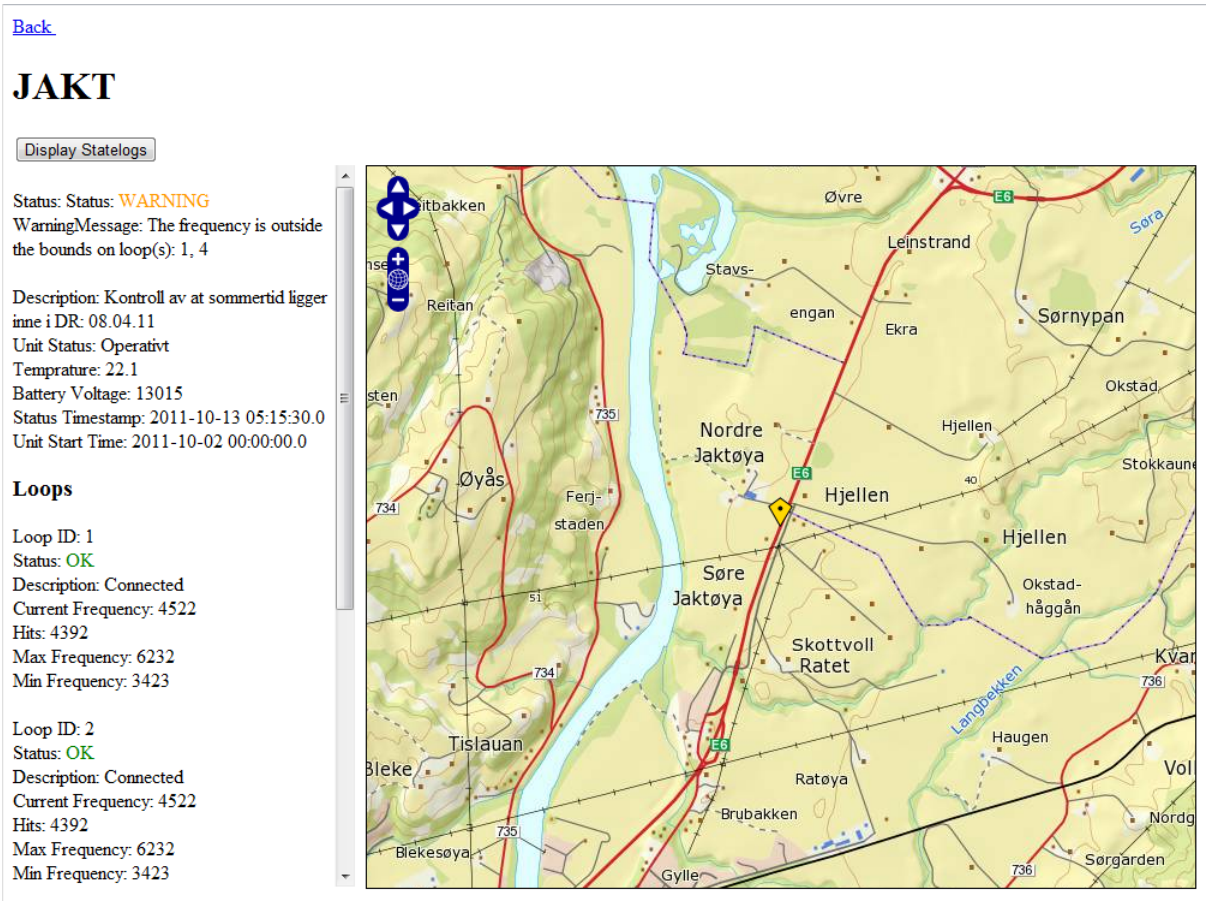
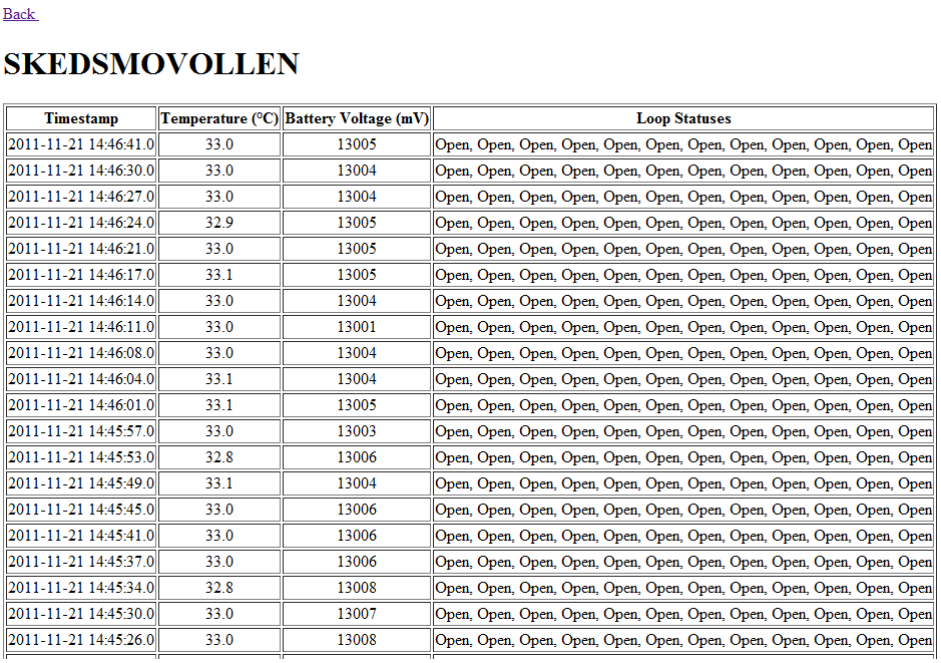


Figure 9.6: Web Page - Display Unit Status

When the user opens the Unit Status page, the information about the current status and its location should be displayed as illustrated in the example above. The user can either click “back”, which will open the front page, or click “Display Statelogs”, which will open a new page that displays the state log of the roadside hardware.



Back

SKEDSMOVOLLEN

Timestamp	Temperature (°C)	Battery Voltage (mV)	Loop Statuses
2011-11-21 14:46:41.0	33.0	13005	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:30.0	33.0	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:27.0	33.0	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:24.0	32.9	13005	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:21.0	33.0	13005	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:17.0	33.1	13005	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:14.0	33.0	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:11.0	33.0	13001	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:08.0	33.0	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:04.0	33.1	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:46:01.0	33.1	13005	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:57.0	33.0	13003	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:53.0	32.8	13006	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:49.0	33.1	13004	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:45.0	33.0	13006	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:41.0	33.0	13006	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:37.0	33.0	13006	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:34.0	32.8	13008	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:30.0	33.0	13007	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open
2011-11-21 14:45:26.0	33.0	13008	Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open, Open

Figure 9.7: Web Page - Display State Logs

The State Log page displays the information about the previous status messages that have been sent from the roadside installations. The State Log offers information about temperature, battery voltage and loop statuses. When the user clicks “Back”, the “Unit Status” page that he came from is displayed. If the user clicks on the arrow-button he will be sent to the page where the incoming Datarec statuses are displayed. This status page displays up to 30 statuses, sorting them from new to old. If there are more than 30 statuses, the user can click to the next page.

10 Discussion of the Implementation

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In this section the discussion of the implementation is presented.

10.1 ONSITE Server

In this section the implementation of the ONSITE Server is discussed.

10.1.1 Rationale

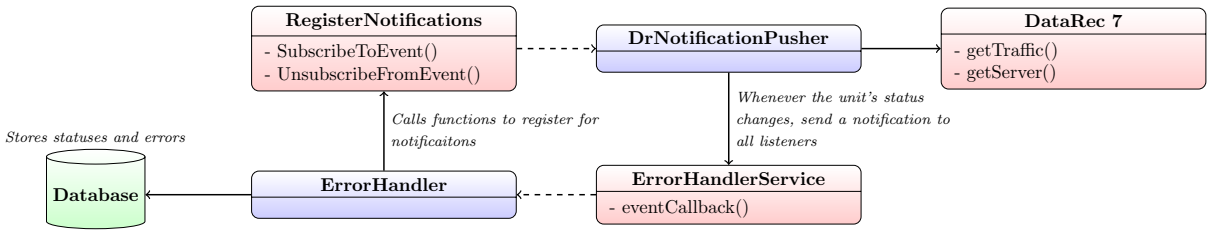

Figure 10.1: Flow Chart

In sprint 2 the we that the OPC-XML protocol had no push-notification method defined. The customer wanted the system to push a status message whenever the hardware detects a change of status, while OPC-XML is a pull-based protocol where the client has to get any updates from last time it connected.

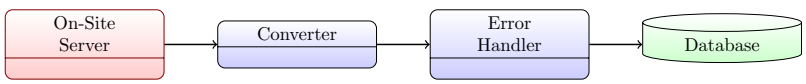

Figure 10.2: ONSITE Server in the System

Due to this we had to come up with a solution for pushing updates from the hardware to the converter.

10.1.2 Details of the Protocol

The protocol pushes status change-events from the hardware to clients subscribed to the events. This means that the protocol follows the publish/subscribe pattern[29], allowing clients to register as an observer of an event and getting notified when it occurs.

Clients use SOAP-calls to subscribe/unsubscribe to an event, returning a unique ID for the client to identify itself to the server.

The calls implemented by us:

- String SubscribeToEvent(String eventName, String callbackPath, String port);
- void UnsubscribeFromEvent(String id);

SubscribeToEvent() allows a client to subscribe to an event if the server knows of the event given. If the call is successful it will give the client an ID to use for identifying itself to the server. Each call to SubscribeToEvent() will generate a new ID.

UnsubscribeFromEvent() allows a client to stop receiving notifications. The client will use the ID given by the server to unsubscribe from said event. Since each ID is bound to a specific event, it is possible to unsubscribe from one event while keeping the rest as is.

10.1.3 Discussion

In this section the discussion of push vs. pull-based protocols and improvements to the implementation is presented.

Push- vs. Pull-based Protocols

A push-based protocol is by design more complex and error-prone than a pull-based protocol. A pull-based protocol can mostly ignore client-side routing issues like NAT, port forwarding, and client changing IP, simplifying the design drastically.

A push-based protocol needs to be able to connect to the client like it was another server, which necessitates punching through routers and firewalls. It also needs know the IP of the client, which often changes over time, unlike most servers. Opening ports to the

outside world will also cause a network security concern, enabling another vector-of-attack for hackers. This can be unacceptable in an organization or business, which makes pushing data to the client much more error-prone and complex.

The advantages of a push-based protocol is that clients are notified the moment an event happens on the server. It also makes it easier to make the server only send new events, removing duplicate events by simply checking against the last event pushed. This is because the server can assume that every client got the last event pushed by the server, while a pull-based protocol would have to store the last event each client pulled.

The advantages can be alleviated by using a couple of tricks with a pull-based protocol. Setting the interval a client polls the server for its status to a lower value will ensure that the client gets each event in a timely manner. When it comes to checking for duplicate events the server can simply ignore it all-together and send the current status each time a client polls. This would put the burden of filtering duplicates on the clients, which is a trivial feature to implement there.

Other Standards

The Datex II v.2.0 standard was brought to our attention near the end of the project. It is backed by the European Commission Directorate General for Transport and Energy, and seems to be specifically aimed at traffic-management and road-side data gathering. It features, among other things, both pushing and pulling of data, a platform-independent data model, and location-based alerts. We think this is a better option for deployment since it has a lot of features that are useful for the NPRA and it is an open standard backed by the EU. It is also reasonable to assume that Datex II will be used by other public road administrations in European countries, which the NPRA might want to cooperate with.

Extending the Protocol

The protocol could be extended with a heartbeat-call, enabling the server to more effectively handle disconnected clients. As of now the server will keep waiting for a timeout when a client is not available anymore, which can take a bit of time. A heartbeat could also be useful for detecting if a client has changed IP-address, and update it locally on the server to ensure a more robust protocol. It is especially useful with mobile clients, as these have a tendency to change addresses more than desktop clients.

Improvements to the Current Implementation

The implementation suffers from having too many points of failure as it is now. The web service runs completely independently of the desktop app, and the server requires both applications to run to work at all. An improvement to this would be to integrate the web service and desktop app into one application that is both server and client at once. This would enable a more robust and elegant method of sharing data, by simply having a shared, thread-safe area of memory both can access. The downside of this approach is that we would have had to implement the SOAP middleware themselves, converting XML-data into a SOAP method call.

The current implementation also calls each client synchronously when a change in status is detected. This means that if a client is unresponsive the server will wait for it to time out before sending the status to the next client. This is not acceptable if the server will serve many clients at once, but can be fairly easily fixed by making each call to a client run in its own thread. It is also possible to use a worker thread pool, allowing multiple calls to clients to be handled simultaneously without the overhead of thread-creation.

Another improvement might be to use another interface for fetching the data off the hardware. The hardware supports other protocols, like ftp, which might be faster than the SOAP-interface. This would alleviate the bottleneck of accessing the status of the hardware, which is fairly slow in the current implementation.

Speed Issues with Datarec

The onsite server tries to pull data from the datarec using its SOAP-interface continuously. We measured that it took from 3s to 5s for the server to fetch a status from the datarec, which puts a bottleneck on the server. By implementing the on-site server on the hardware itself it might be possible to avoid this bottleneck.

10.2 Error Handler

The Error Handler turned out to be the most complex component of the system, and since we had the impression that the developed system would be useful to the customer, we decided to implement every single bit of it, even though it was very time-consuming. If it would have been clearer for us that the research done during the implementation of the ONSITE server was the most interesting part of the project, we would have dedicated more hours to that instead of the Error Handler.

The Error Handler has checks for detecting if:

- a loop has a short circuit

- the current frequency is outside the bounds
- the battery voltage is below a predefined minimum
- the connection with the Datarec unit has timed out

These error checks only detect some of the possible errors. A suggestion would be to also implement checks that detect if:

- the temperature of the Datarec unit is outside the bounds
- the average speed of the counted vehicles is negative (suggests that the loops has been installed wrong)
- the average speed of the counted vehicles is way higher than the speed limit (suggests that the loops has been installed wrong)
- a connected loop suddenly "disappears" from the Datarec unit (suggests that the loop has "died")

This would widen the search for errors and make the data from the Datarec units more reliable.

10.3 Web Service

There is not so much to discuss when it comes to the Web Service. It is a very simple web service that gives access to the data in the *Datarec* database, and can easily be extended to obtain desired functionality. The only thing worth mentioning is that it has no way of suppressing or deleting errors from the database. If a Datarec unit has an unresolved error when removed from the system, the Web Service would always report that error as unresolved and there would be no other way of deleting the error than to manually deleting it from the database. A simple extension of the Web Service would solve this problem.

10.4 Web Page

This section describes the details about the implementation of the web page part of the system.

10.4.1 Exception Handling

The Web Page is responsible for handling the SOAPException_Exception that is thrown from the Web Service, and the error caused when the Web Page is unable to connect to

the Web Service. This is handled by displaying an error page instead of the usual Web Page when the error is thrown. The error page is implemented using a test that checks whether the Web Page is able to successfully gather the necessary information to load the page (using the Java try/catch statement). The error web page displays a clean web interface, informing that an error has occurred and displaying the error message involving the exception.

10.4.2 Improvements

Since this is developed as a proof-of-concept, the Web Page functionality and its graphical user interface have not been prioritized as highly as it would have been in a further developed system. The designing of a web page is a time-consuming task, and we simply could not spare the time for it.

After using our Web Page a while we have had some ideas that could increase the usability of the Web Page. These improvements are presented and explained below.

Functional Improvements

This list is a suggestion of functional improvements on the web page.

- The web page should be able to auto-update the information about the roadside hardware statuses without having to refresh the entire page.
- The web page should be able to load the information faster than it actually does in the current implementation. In order to achieve this, the access to the database has to be faster, and the web service should limit its interaction with the database more. It would also be a good idea to have a cache that keeps the images that are loaded most often, since the loading of images in the map is quite time consuming.
- The errors that occur in the error-reporting system should all be displayed on the Web Page; this would make the error-reporting system more reliable, since the user will have easier access to information about system failures.

Graphical Improvements

This list is a suggestion of graphical improvements on the web page.

- When the user is looking at a unit with an error, a graphic illustration should show exactly which piece of hardware internally in the unit that has an error. An example would be that when a loop has failed, the Web Page would display all the loops and mark which one of them that has failed.

- When the user clicks on the marker of the hardware unit, a pop-up message describing its status message should appear.
- The state logs should involve more information. It should also display a graph that displays the evolution of the unit state. This would help to identify the nature of warnings. Here is an example with the temperature: The temperature can be high during a small amount of time, which is not critical, but if the temperature is rising during a long period of time, it could indicate an error in the cooling system of the hardware.
- The overall design of the Web Page should match the design of the internal system to the customer, because this would increase the usability of the page.
- The GUI of the Error Handler should be extended into the Web Page to make it easier for the user to connect to the on-site servers.

Part III In Retrospect

11 Project Evaluation

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11.2 Becoming a Team 108
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This section contains the evaluation of the project as a whole and of the different parts of the project.

11.1 Cultural Differences between the Students

Our student group consisted of seven students, six of whom were Norwegian. The seventh group member was an international Masters degree student from Nepal. This resulted in English as the main language for communication throughout the project.

Although most of us mastered English to an acceptable level, some were better than others. Most of us were not used to speaking English, which initially made the oral communication rather stuttering and poor. It would actually appear to be a surprisingly big problem for communication at the first few meetings.

The broken English presumably made several group members act more shyly than they usually would. Consequently the internal ice-breaking in our group got off to a worryingly slow start. After two weeks we got together in our spare time to have a meal together, socialize and get to know each other. This social meeting and the first lecture on group dynamics made us more comfortable with each other, and lead to communication gradually going more smoothly.

11.2 Becoming a Team

Some of us knew each other a bit from before, and some did not know anyone. This is a typical start on the project for a group that was randomly put together. Using Tuckman's theory for team development, there were four possible stages.

1. Forming
   Getting to know each other
2. Storming
   Challenging each other
3. Norming
   Working together
4. Performing
   Working as one

The first phase is the Forming phase. Here the team members try to get to know each other. The language barrier made this phase a little problematic for us, but the transition to phase two still went very fast for most of us. A reason for this might be that some of us knew each other from before.

The second phase did not last long, and there have been few big confrontations or loud arguments. The transition to phase three came fast for most members of our team.

Third phase is the phase where people work together, help each other out and are supportive. This is the stage most of us were on for the main duration of the project.

Phase four is the last, and the optimal, state to be in. Our team did not enter this state. The main reason for this is the duration of the project. Normally, in small projects like this one, groups do not enter this phase due to the lack of time. [15]

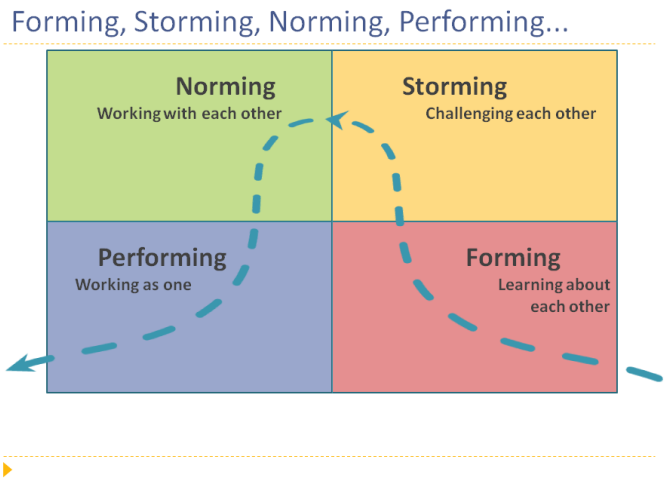

Figure 11.1: Tuckman's Theory

11.3 Inefficiency and Internal Information Flow

Information flow internally in our group was somewhat messy in the start, and we did not manage to be as elaborate in distributing work tasks as we should have been. This is especially noticeable in the report, which did not have the progress that it was expected to have.

It took about two weeks before we finally got around to define and assign roles among us. At this point the low productivity of our group was starting to be slightly concerning, and the advisor told us that we had to assign roles and distribute work tasks to try and increase our efficiency. In the process of defining roles we came up with a practically redundant role called "PR-manager". Most of the contact between the customer/advisor and the group has gone through the secretary, and nearly all meetings were agreed to be held weekly. Consequently the PR-manager role has not had any practical use at all.

11.4 Contact with the Customer

The customer was represented through Jo Skjermo and Kristin Gryteselv. Gryteselv was the originator of the project, and Skjermo acted as the main customer representative. We met with Skjermo once a week at our regular meetings.

We had a very pleasant tone with Skjermo in our meetings, and there were never any arguments or strained atmospheres.

11.5 Utilizing the Advisor

In previous years the student groups have been assigned two advisors. This year however, the teams were assigned only one advisor. The advisor's responsibility to the student group is to oversee that the project process has the right progress, and that the students maintain sufficient contact with the customer.

Throughout the project period the team and the advisor held weekly meetings where the advisor gave us much needed feedback on the project documentation, as well as suggestions on how to best handle the situation they were in. These meetings lasted for about an hour every week. In addition to these meetings the advisor was available for questions in his office and by mail every work day.

11.6 Risks that Became Problems

In the planning phase of the project we identified a number of risks that may decrease the quality of the end product if such a risk should occur. The following items from the risk assessment section have come true: Illness, communication problems, lack of experience, wrong priorities, technical issues and delayed deliveries.

Wrong Priorities One of the risks that was assessed in the report was the risk of group members that do not prioritize the project as highly as expected. Unfortunately this was the case for some of the members of our group. As a consequence of this we have struggled with reaching the expected amount of person hours every week, and in the end we had to drop some of the requirements with low priority.

Sickness Another foreseen risk was sickness. Since autumn is a time of year where the weather takes a turn for the worse, it was no big surprise that several group members became sick and needed some days off to recover. After this it would seem that we had underestimated the risk assessment for sickness in the initial planning phase of the project. They decided to upgrade the probability of this risk, as it had affected the amount of person hours in a more negative way than expected.

Customer Delays In the start of the project, the customer had problems with setting up the equipment necessary for us to start testing. An important database dump and a connection to the Datarec hardware were the two biggest and most important delays. They were both delivered in the start of October. This resulted in a late start for us, after a period of time where work tasks were limited.

Communication Problems As the section about language explained, we experienced a language barrier. Because several of our group members were uncomfortable with expressing themselves in English, the discussions at meetings did not always have a very good flow. The communication problems hit an all time low when we visited the Norwegian Public Roads Administration's office for a lecture with their experts. The experts had not been made aware that their presentation should have been in English. Consequently they showed up with Norwegian PowerPoint slides and were completely caught off guard, as they struggled with expressing themselves in English.

Lack of Experience The distribution of work tasks, the planning and the report writing were all aspects of the project that were characterized by the fact that we were not very experienced with such big projects. In the beginning of the project, the way that we distributed tasks was kind of unorganized. Most of the time we just "found something

to do" on our own initiative. This way of working can be very inefficient. Luckily we got much better at this after a while, and increased our productivity.

When we made the project plan, we assumed that every student would manage to work 25 hours every week throughout the whole semester. This was much too optimistic. After three weeks we realized that we were already behind schedule, which was quite disappointing. Luckily, once our group started producing code in the first sprint, they were able to finish several important implementations in significantly less person hours than what was planned for. This made up for much of the lost time.

None of us had any significant experience with producing such elaborate technical documentation that is required for the Customer Driven Project. This has made the project report very time consuming, and we soon realized that we might have underestimated the time it would take to write the report.

Technical Issues We lost about three days worth of testing due to a bug with the Datarec 7 hardware, which was that the Datarec reset its own IP address whenever we tried to connect to it through remote desktop. When the Datarec and the server laptop was installed on-site three work days later, the bug was fixed.

Four weeks before our final presentation, the ICE modem in Moholtlia stopped working. It was not fixed until three weeks had passed. Because of this we did not get to show the customer how our system would work with their actual hardware installations, instead of just with out mocked up version of it.

11.7 Changes in Requirements

Changes of the requirements are common when having an agile development method. We lost a lot of time in sprint 2 when our biggest requirement had to be reworked. We were already deep into implementing an OPC server, when we found out that had to scrap it and start over with a new server implementation. The changes of our requirements specification are presented in Appendix C: Requirements Specification.

11.8 Initial Backlog

As the Scrum phase came close, we realized that the product backlog which we had designed should have been much different. Therefore we redesigned it so that every sprint would produce separate parts of the final system. This design makes for a clearer sense of progress and gives us finalized implementations that we can show to the customer. In retrospect, we are wondering if the best way to design the sprints would have been to

aim to implement a minimum of the highly prioritized requirements to make a functional system in sprint 1, and then further extend the system in the following sprints.

Part IV Appendices

A Appendix: Testing

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This section includes a more detailed elaboration on the requirement tests.

A.1 Display Unit Information

In this section the testing of displaying unit information is presented.

Test ID	T01
Description	Test if the Web Page's unit part is working as intended.
Requirement ID	FR20
Test criteria	The Web Service must be functional and have information about the hardware units available.
Task	1. Open Web Page 2. Select a hardware unit 3. Open unit information
Expected output	The Web Page should display an overview of all the information relevant to the selected unit's status.
Result	Passed
Comments	The test went without any irregularities. The test is passed because the expected output matches the real output. The Web Page was slow during the test with the system integrated.

A.2 Display State Logs for Units

Test ID	T02
Description	Test if the Web Page's log part is working as intended.
Requirement ID	FR24
Test criteria	The Web Service must be functional and and have information about the hardware units available.
Task	1. Open Web Page 2. Select a hardware unit 3. Open unit log
Expected output	The Web Page should display on overview of all the previous logged incidents with any relevant information.
Result	Passed
Comments	The Web Page behaved like it was supposed to. The Web Page was quite slow, but that is documented in T01.

A.3 Map Service

Test ID	T03
Description	Test if the Web Page's map service is working as intended.
Requirement ID	FR19
Test criteria	The Web Service must be functional and and have information about the hardware units available.
Task	1. Open Web Page 2. Jump to Datarec 7 unit
Expected output	1. The Web Page should open and show a map with the hardware that has errors displayed with a red marker and working hardware displayed with a green marker. 2. The map should be placed zoomed with the selected hardware in the center.
Result	Passed
Comments	The test went without any irregularities. The Web Page was slow during the test with the system integrated.

A.4 Web Service

In this section the testing of the Web Service is presented.

Test ID	T04
Description	Testing the Web Service connection to the NorTraf database abstraction.
Requirement ID	FR17
Test criteria	Working NorTraf database abstraction connection.
Task	Send a request to the Web Service for coordinates to the NorTraf database for a Datarec 7 with ID 10718(placed at Klett).
Expected output	The coordinates should be (265665.6,7030217.5).
Result	Passed
Comments	The coordinates were placed in our database, which means that the connection to the NorTraf database would not be tested in this test. This was due to the fact that we did not have accsess to the NorTraf database. But the system was successfully able to give the correct coordinates, and was considered successful.

Test ID	T05
Description	Test whether the Web Service is able to accept connections from a SOAP client.
Requirement ID	FR15
Test criteria	The tester must have access to a SOAP-client.
Task	Try to set up a connection to the SOAP interface to the Web Service using the Web Page.
Expected output	The Web Service should accept the connection from the Web Page.
Result	Passed
Comments	The tester was successfully able to set up a working connection between the Web Page and the Web Service using SOAP. The tests were carried out both by running the server and the client on one single computer, and by running them on separate computers. The test went without any irregularities, and was accepted.

Test ID	T06
Description	Test to confirm that the Datarec database is able to offer status and errors messages to the Web Service.
Requirement ID	FR16
Test criteria	The system should have a Web Service and a Datarec database.

Continued on next page

Table A.6 – continued from previous page

Task	1. Set up a connection between the database and the Web Service. 2. The tester should make the Web Service get two status messages from the database. 3. The tester should make the Web Service get two error messages from the database.
Expected output	1. The connection should be established. 2. The Web Service should receive the status messages. 3. The Web Service should receive the error messages.
Result	Passed
Comments	The system was able to get the status messages and the error messages successfully. This implies that the communication between the database and the Web Service worked appropriately, and the test was successful.

Test ID	T07
Description	A test which confirms that the Web Service is enable to separate warnings and errors
Requirement ID	FR18
Test criteria	The system should be able to produce warnings and errors messages.
Task	1. Input a warning message to the Web Service 2. Input a error message to the Web Service
Expected output	1. The error and warning messages should be distinguished.
Result	Passed
Comments	The errors and warnings are separated in the database by a flag. The Web Service gets this flags and sets it “w” for warning and “e” for errors. The system was successful in this task, and it was possible to distinguish between errors and warnings.

A.5 Datarec Database

In this section the testing of the database is presented.

Test ID	T08
Description	This test is supposed to confirm that the database is able to store the error messages and warnings.
Requirement IDs	FR13 and FR14
Test criteria	Have the database running.
Task	1. Add a warning message stating that it is to high temperature on the Datarec with ID 9410. 2. Add an error message saying that there is an error in loop 1 on the Datarec with ID 9725.
Expected output	The warning message and the error message should be added in the database.
Result	Passed
Comments	The database was working correctly. It is possible to store and get data from the database in the approriate way. The test is therefore considered to be successful.

A.6 Datarec 7 SOAP Client

In this section the testing of the Datarec 7 SOAP Client is presented.

Test ID	T09
Description	This test should make sure that requirement FR1 and FR2 is implemented in the system. This means that it should test if the connection using the SOAP interface is working properly.
Requirement IDs	FR1 and FR2
Test criteria	This test needs a working Datarec 7 connected to an Ethernet connection and a working SOAP client to access the interface.
	Continued on next page

Table A.9 – continued from previous page

Task	The SOAP client should access the following information on the Datarec 7 hardware using the SOAP client: 1. The loop connection status. 2. The loop hits. 3. The loop frequency status. 4. The start time. 5. Battery voltage. 6. Temperature. 7. Most recent vehicle information. 8. The accumulated number of vehicles and their speed.
Expected output	When checking the result against the information listed using the HTTP service of the Datarec 7, the information should match.
Result	Passed
Comments	The system gets the right result from the Datarec 7, but the process of fetching data is a bit slow. The hardware uses 3-5 seconds when it responds to requests from the SOAP client. We think this happens because of the overhead that comes with using SOAP. The converting to XML and setting up HTTP takes some time, and the hardware in the Datarec 7 is slow. We considered the problem to be unsolvable, and therefore simply accepted the poor result.

A.7 Error Handler

In this section the testing of the Error Handler is presented.

Test ID	T10
Description	This test is constructed mainly to test whether the connection between the ONSITE server and the Error Handler is working correctly. But it also tests the connection between the Error Handler and the NorTraf database, to check that it is successfully able to get IP addresses from the database.
Requirement ID	FR7, FR8 and FR9
Test criteria	There should exist at least one working ONSITE server.

Continued on next page

Table A.10 – continued from previous page

Task	1. The Error Handler should connect to the ONSITE server using the Error Handler's GUI and the IP address of the ONSITE server. 2. The on-site server should add the error handler as a listener. 3. The ONSITE server should send a error message to the Error Handler, using the connection that was set up.
Expected output	1. The GUI should show the IP address of the ONSITE server in the list of IP addresses. 2. The connection should be successfully set up, and the ONSITE server should now be able to send messages to the Error Handler. 3. The Error Handler should receive the error message.
Result	Passed
Comments	The setup with the ONSITE server worked satisfactorily, and the connection was successfully set up. The Error Handler successfully received the message from the ONSITE server. The testing of whether the Error Handler was able to get the IP address from the NorTraf database was hard to check in a satisfactory way, because the database we got from the costumer only had telephone numbers stored. We added the IP address manually to make it possible to test, and then it was successful. Another issue is that we did not have access to the real NorTraf database during the project, so the costumer needs to test this feature themselves with access to the database. The Error Handler is equipped with Oracle drivers (the NorTraf database is an Oracle database), so this should be working properly. Since this feature was fully functional on our prototype, it should be working on their system as well, and is therefore considered successful.

Test ID	T11
Description	This is a test constructed to test if the Error Handler i capable of handling all planned errors.
Requirement ID	FR10

Continued on next page

Table A.11 – continued from previous page

Test criteria	A mock up of the ONSITE server, which is capable of sending data containing all the necessary errors. The connection between the ONSITE server and the error handler should be set up.
Task	1. The ONSITE server should send a message containing information stating that there has been a short circuit. 2. The ONSITE server should disconnect the network connection.
Expected output	1. The messages should be added in the database. 2. The Error Handler should catch the timeout, and add a timeout warning in the database.
Result	Passed
Comments	The Error Handler successfully recognized the errors and added them into the database. The test is therefore considered successful.

Test ID	T12
Description	This test will make sure that the Error Handler is capable of handling errors and warnings, while there also is data which do not provides any information about errors.
Requirement ID	FR11 and FR12
Test criteria	Atleast one on-site server should be set up and running. It should be able to send errors, warnings and traffic data to the Error Handler. The Database should be running, so the Error Handler could store the data.
Task	1. Mock up 10 error free data messages in the on-site server, and send them to the error handler. 2. Send a warning about frequencies being to high. 3. Send a new message without error. 4. Send a message containing information about a short circuit.

Continued on next page

Table A.12 – continued from previous page

Expected output	1. The warning message should be added in the database, containing a flag W, informing that it is a warning. 2. The error message should be added in the database, containing a flag E, informing that it is an error. 3. All the other data messages should be rejected.
Result	Passed
Comments	After the test was completed, the only data that was added in the database was the error and warning messages. This implies that the test was successful, and had passed. Since the error handler shows the correct behavior.

A.8 ONSITE Server

In this section the testing of the ONSITE Server is presented.

Test ID	T13
Description	This is a test that should confirm that the ONSITE server is able to automatically push data and to register the Error Handler as its listener.
Requirement ID	FR4 and FR5
Test criteria	A mock up of the Datarec 7 SOAP client needs to be running to produce the errors and the Error Handler must be running and able to send request to register itself as a listener.
Task	1. The Error Handler should connect to the ONSITE server, using the on-site servers IP address. 2. The mocked up SOAP client should produce an error.
Expected output	1. The ONSITE server should accept the connection, and send an accept message to the Error Handler. 2. The ONSITE server should automatically push the error message to the Error Handler.
Result	Passed

Continued on next page

Table A.13 – continued from previous page

Comments	The reason for using a mocked up Datarec 7 SOAP client instead of a real Datarec 7, is that we had no way to produce the error at the Datarec 7 location. The test went without problems, the connection to the Error Handler was successfully established and the pushing was working satisfactorily. This also suggests that the Error Handler's part is working according to plan. Therefore, the test was considered successful.

B Appendix: Templates

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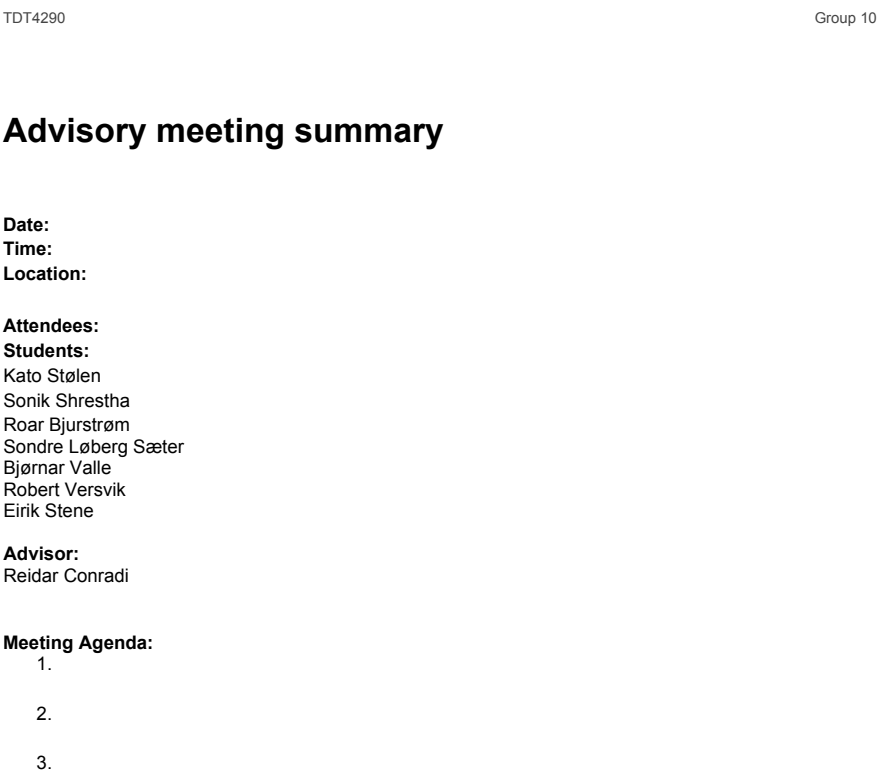
B.5 Work Sheet Template 127
B.6 Test Table Template 127

In this section the different templates used during the project are presented.

B.1 Advisory Meeting Summary Template

In this section the template for advisory meetings is presented.



TDT4290 Group 10

Advisory meeting summary

Date:
Time:
Location:

Attendees:
Students:
Kato Stølen
Sonik Shrestha
Roar Bjurstrøm
Sondre Løberg Sæter
Bjørnar Valle
Robert Versvik
Eirik Stene

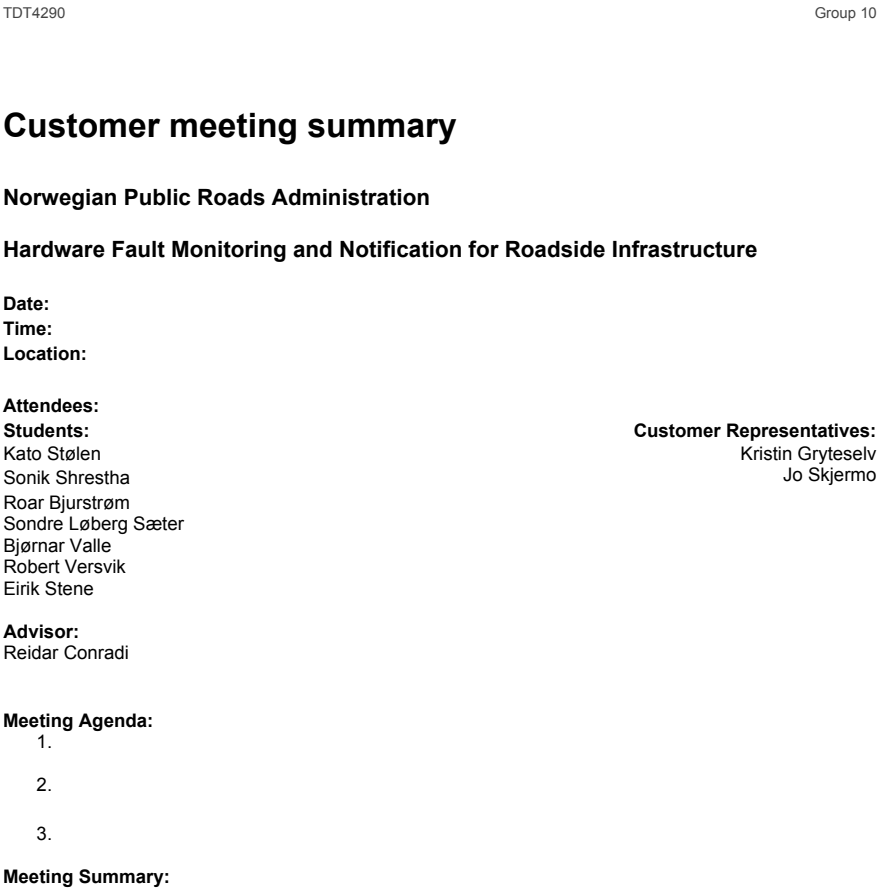
Advisor:
Reidar Conradi

Meeting Agenda:
1.
2.
3.

Figure B.1: Advisory Meeting Summary Template

B.2 Customer Meeting Summary Template

In this section the template for customer meetings is presented.



TDT4290 Group 10

Customer meeting summary

Norwegian Public Roads Administration

Hardware Fault Monitoring and Notification for Roadside Infrastructure

Date:
Time:
Location:

Attendees:

Students:
Kato Stølen
Sonik Shrestha
Roar Bjurstrøm
Sondre Løberg Sæter
Bjørnar Valle
Robert Versvik
Eirik Stene

Customer Representatives:
Kristin Gryteselv
Jo Skjermo

Advisor:
Reidar Conradi

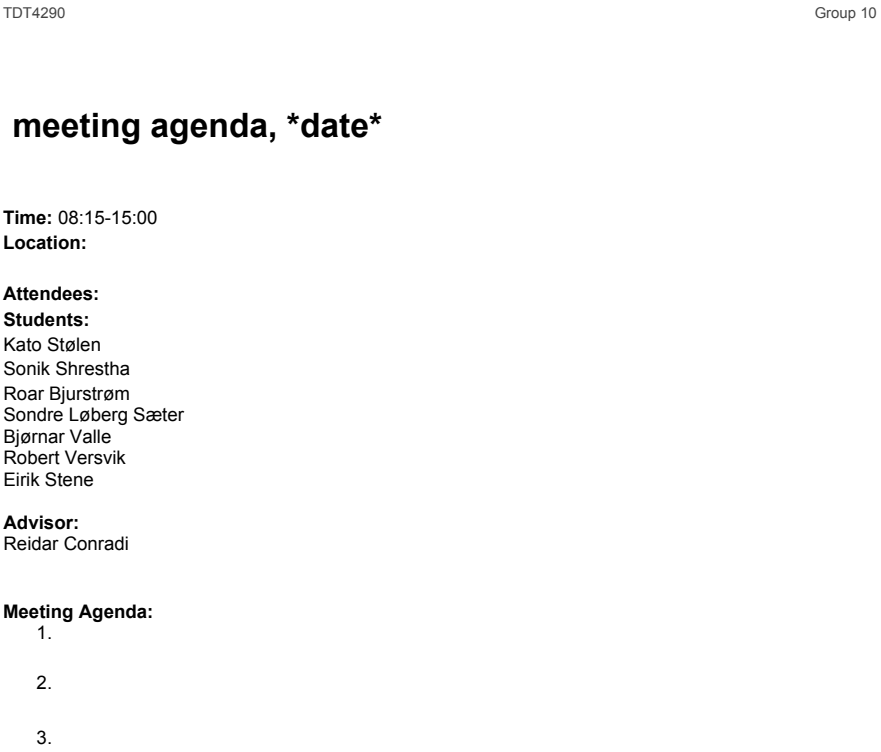
Meeting Agenda:
1.
2.
3.

Meeting Summary:

Figure B.2: Customer Meeting Summary Template

B.3 Meeting Agenda Template

In this section the template for meeting agendas is presented.



TDT4290 Group 10

meeting agenda, *date*

Time: 08:15-15:00
Location:

Attendees:
Students:
Kato Stølen
Sonik Shrestha
Roar Bjurstrøm
Sondre Løberg Sæter
Bjørnar Valle
Robert Versvik
Eirik Stene

Advisor:
Reidar Conradi

Meeting Agenda:
1.
2.
3.

Figure B.3: Meeting Agenda Template

B.4 Status Report Template

In this section the template for status reports is presented.

TDT4290 Group 10

Status report Group 10, week

Meetings and summary for this week:

What was good?

What was bad?

What must be improved?

Person hours

	Roar	Bjørnar	Kato	Sondre	Robert	Sonik	Eirik	Sum
Planning								
Pre-study								
Sprint1								
Sprint2								
Sprint3								
Report								
Sum								

Figure B.4: Status Report Template

B.5 Work Sheet Template

In this section the template for work sheets is presented.

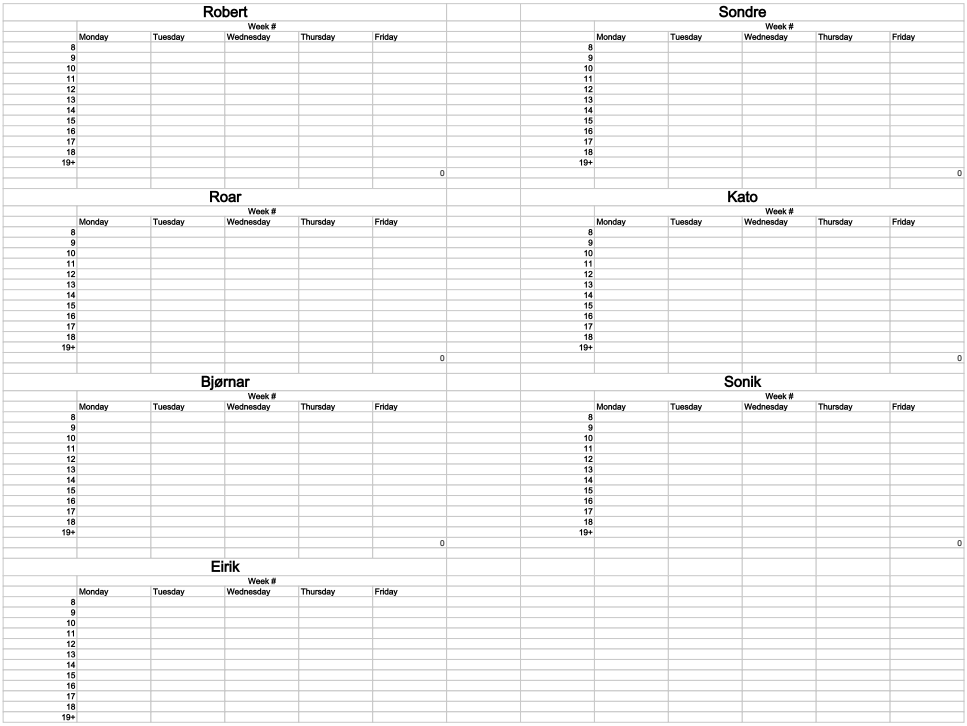

Robert
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Sondre
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Roar
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Kato
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Bjørnar
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Sonik
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+
0
Eirik
Week #
Monday Tuesday Wednesday Thursday Friday
8 9 10 11 12 13 14 15 16 17 18 19+

Figure B.5: Work Sheet Template

B.6 Test Table Template

In this section the template for test tables is presented.

Test ID	Identification of each test.
Description	Description of the test's purpose.
Requirement ID	Maps each test to an item in the requirements specification.
Test criteria	Criteria for the test to be able to complete dependencies of other modules.
Task	List of tasks to perform during the test.
Expected output	States the expected results by running the test.
Result	States whether the test succeeded.
Comments	Notes on the test.

Table B.1: Template for Functionality Tests

C Appendix: Initial Requirement Specification

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This section shows how our requirement specification was at the beginning of the project.

C.1 Functional Requirements

ID	Description	Priority
1. Continuously fetch data from Datarec 7 installations		
FR1	The system should support the Datarec 7 hardware.	High
FR2	The system should use the SOAP interface to get the status of the Datarec 7 hardware every second.	High
11. Set up OPC server		
FR3	The server OPC server should offer a mock-up of a subset of the OPC functionality.	High
FR4	The server OPC server should be able to register listeners.	High
FR5	The OPC server should be able to push data.	High
10. Fetch network statistics		
FR6	The system should use RMON to fetch statistics describing network traffic.	High
12. Set up OPC client		
FR7	The OPC client should be able to receive messages from the OPC server.	High
FR8	The OPC client should be able to register itself as a listener to the OPC servers.	High
FR9	The OPC client should get a list of all the roadside installations and their IP-addresses from the NorTraf database abstraction level.	High
7. Detect errors and faults		
FR10	The system should use the data from the network monitor and OPC server to detect network irregularities, peculiar data, loop faults, hardware faults or wrong hard-wiring.	High

Continued on next page

Table C.1 – continued from previous page

ID	Description	Priority
FR11	The errors should be separated from the regular data messages.	High
FR12	The error handler should create warnings on irregularities and peculiar data.	High
2. Save data in database		
FR13	The system should use a SQL database to store the statuses and errors.	High
FR14	The system should convert the messages from the OPC server and network monitor for database storage.	High
3. Set up web service		
FR15	The system should have a web service using SOAP.	High
FR16	The web service should use the SQL database to offer status and error data.	High
FR17	The web service should use the NorTraf database abstraction to get the coordinates of the roadside installations.	High
FR18	The web service should separate warnings and errors.	High

Table C.1: High Priority Functional Requirements

ID	Description	Priority
4. Show location of roadside installations on a map		
FR19	The system should use a map service to show the locations of the roadside installations on a map.	Medium
5. Display unit information		
FR20	The system should display the status of separate installations in a web page.	Medium
8. Add support for Datarec 410		
FR21	The system should support the Datarec 410 hardware.	Medium
FR22	The server on-site should run Traffic6 to get data from the DataRec 410.	Medium
FR23	The OPC server should parse and offer the data from Traffic6.	Medium
14. Display state logs for units		
FR24	The system should store the states of the separate installations in a database.	Medium

Table C.2: Medium Priority Functional Requirements

ID	Description	Priority
15. Automatic notifications		

Continued on next page

Table C.3 – continued from previous page

ID	Description	Priority
FR25	The system should notify by SMS or email automatically if errors occur.	Low

Table C.3: Low Priority Functional Requirements

C.2 Non-Functional Requirements

ID	Description	Priority
13. Create installation guide and user manual		
NFR1	The system should have a installation guide and user manual.	Medium
9. More extensive design of web interface		
NFR2	The web interface should have a clear design.	Low
NFR3	The web interface should use Ajax to enhance user experience.	Low
Other		
NFR4	The system should be programmed in Java/Java Enterprise.	High
NFR5	The system should be easy to integrate into the customer's existing system.	High

Table C.4: Non-Functional Requirements

C.3 Changes in Requirement Specification

The requirements had to be changed during the project, because the technologies that were initially suggested had some technical limitations. There have been some name changes of things during the project. The server which was been named "the OPC server" has been renamed into the ONSITE server in the final report. The ONSITE server refers to the server computer which is placed by the roadside installations. This causes some minor fixes on requirements that refers to product backlog ID 11.

There was also a name change in the "detect error" part, it is now called the Error Handler. The Error Handler also includes parts of what previously had been called the "OPC client". The original requirement specification can be found in Appendix C, while the updated version can be found in chapter 4.

FR3 had to be changed due to the fact that the OPC server did not have the possibility to push data, which actually makes it impossible to implement the way the original requirement was stated. The solution to this problem was to implement a server which

mimics the OPC functionality, but also includes the possibility to add other features. The priority remained the same after the change.

FR5 had to be changed since it at the beginning required it to be the OPC server that pushes the data. Since OPC did not support the feature, we had to change the requirement as well, since it could not be based on OPC.

FR6 had to be removed completely, since our system operates through the Internet. Initially the Error Handler was supposed to fetch statistics using RMON from the routers along the connection path and report connection errors. Since the information we needed from the routers along this path are not assessable by others than the Internet service providers, it would be impossible to implement. We had the option to implement the RMON protocol on the local network that the servers are installed on, but this was not seen as a useful enough tool.

FR14 The database was initially able to handle storage of network statistics as well as the other errors and warning messages. But since the fetching of the network statistics was removed from the project, there were no longer any network statistic to store. Therefore we removed this feature from the database.

FR 21,FR22 and FR23 were removed because the support for Datarec 410 was not an important part of the project. Since this is a proof of concept, the support to Datarec 410 is not crucial. Another issue is that the Datarec 410 is independent from the Traffic6, which does not support real time data. The customer wishes to have a product which is not dependent on Traffic6. All new hardware installed is Datarec 7, so the necessity to support Datarec 410 will disappear in the future. This causes all of the requirements related to the Datarec 410 to disappear.

C.4 Inital Product Backlog

In this section the initial product backlog is presented.

ID	Description	Total Effort Estimate	Sprint 1	Sprint 2	Sprint 3
	High Priority				
1	Continuously fetch data from Datarec 7 installation	105	70	35	0
11	Set up OPC server	190	0	130	60
10	Fetch network statistics	80	0	80	0
12	Set up OPC client	85	0	25	60
7	Detect errors	110	65	45	0
2	Save data in database	70	70	0	0
3	Set up web service	135	135	0	0
	Medium Priority				
4	Show location of roadside installations on a map	55	55	0	0
5	Display unit information	30	30	0	0
8	Add support for Datarec 410	90	0	0	90
13	Create installation guide	40	0	0	40
14	Display state logs for units	50	50	0	0
	Low Priority				
9	Design web interface	20	0	0	20
6	Automatic notifications	45	0	0	45
	Sum Hours	1105	475	315	315

Table C.5: Product Backlog

D Appendix: Design

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In this section the design of the system is presented.

D.1 Common Library

In this section the design of the common library is presented.

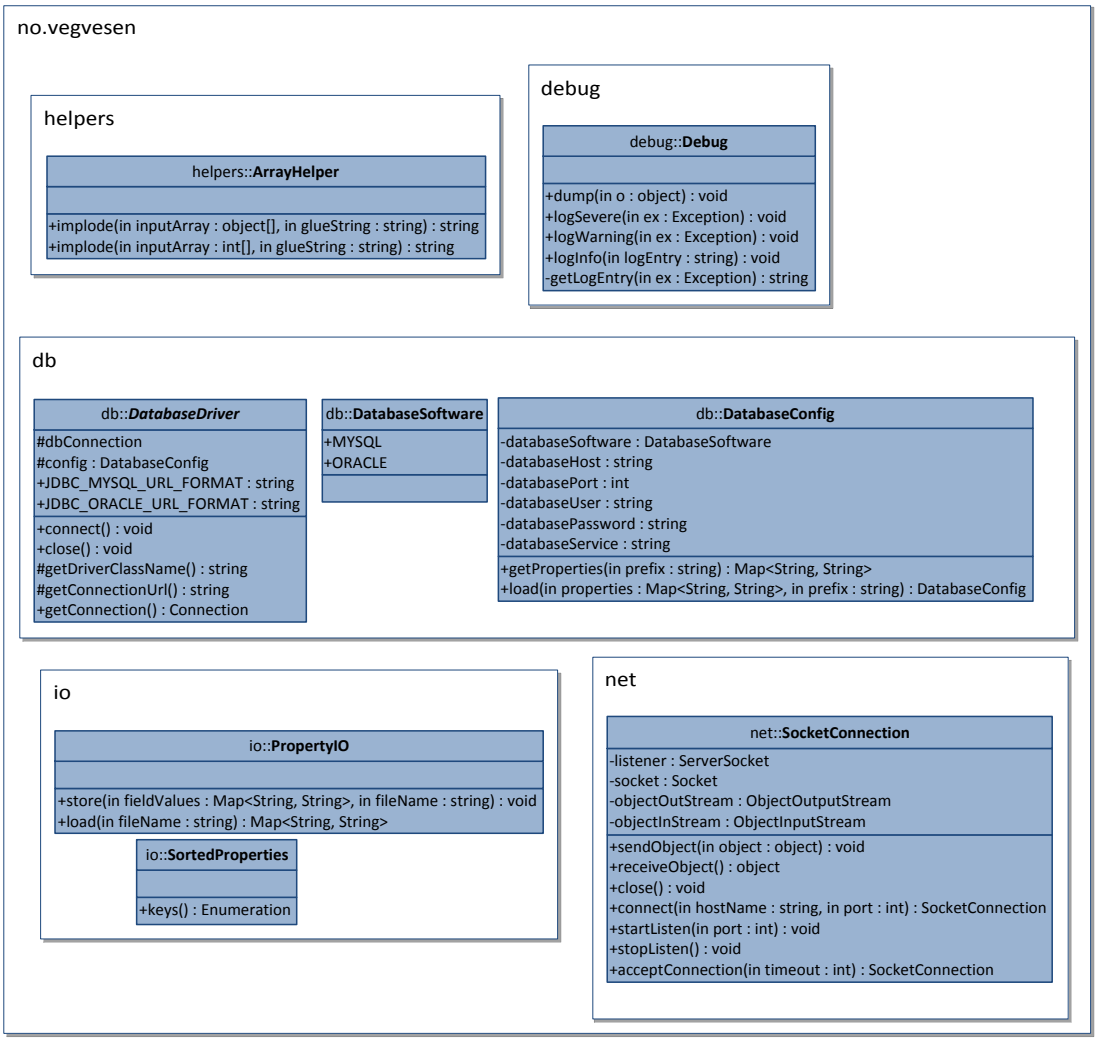

Figure D.1: Overview Class Diagram of the Common Library

D.2 Web Page

In this section the design of the Web Page is presented.

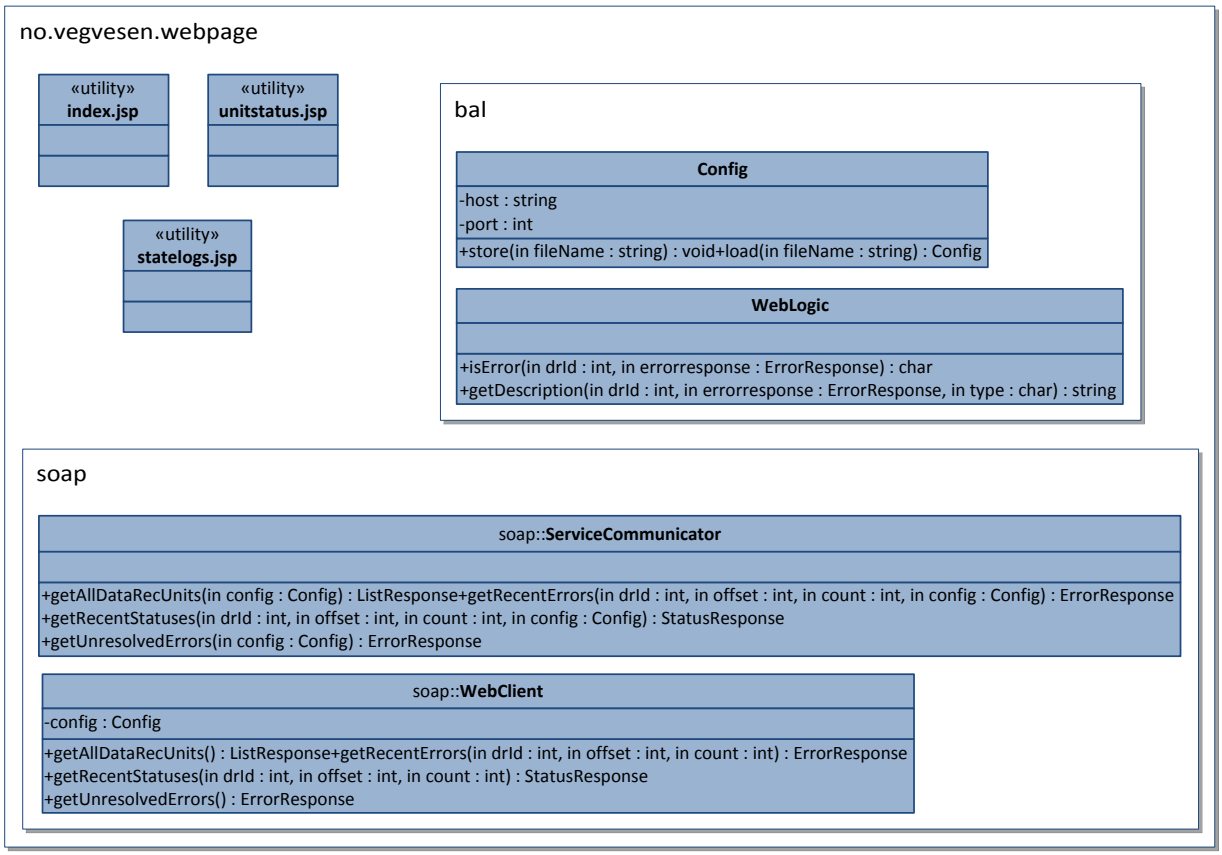
no.vegvesen.webpage
«utility»
index.jsp
«utility»
unitstatus.jsp
«utility»
statelogs.jsp
bal
Config
-host : string
-port : int
+store(in fileName : string) : void+load(in fileName : string) : Config
WebLogic
+isError(in drId : int, in errorresponse : ErrorResponse) : char
+getDescription(in drId : int, in errorresponse : ErrorResponse, in type : char) : string
soap
soap::ServiceCommunicator
+getAllDataRecUnits(in config : Config) : ListResponse+getRecentErrors(in drId : int, in offset : int, in count : int, in config : Config) : ErrorResponse
+getRecentStatuses(in drId : int, in offset : int, in count : int, in config : Config) : StatusResponse
+getUnresolvedErrors(in config : Config) : ErrorResponse
soap::WebClient
-config : Config
+getAllDataRecUnits() : ListResponse+getRecentErrors(in drId : int, in offset : int, in count : int) : ErrorResponse
+getRecentStatuses(in drId : int, in offset : int, in count : int) : StatusResponse
+getUnresolvedErrors() : ErrorResponse

Figure D.2: Overview Class Diagram of the WebPage

D.3 Web Service

In this section the design of the Web Service is presented.

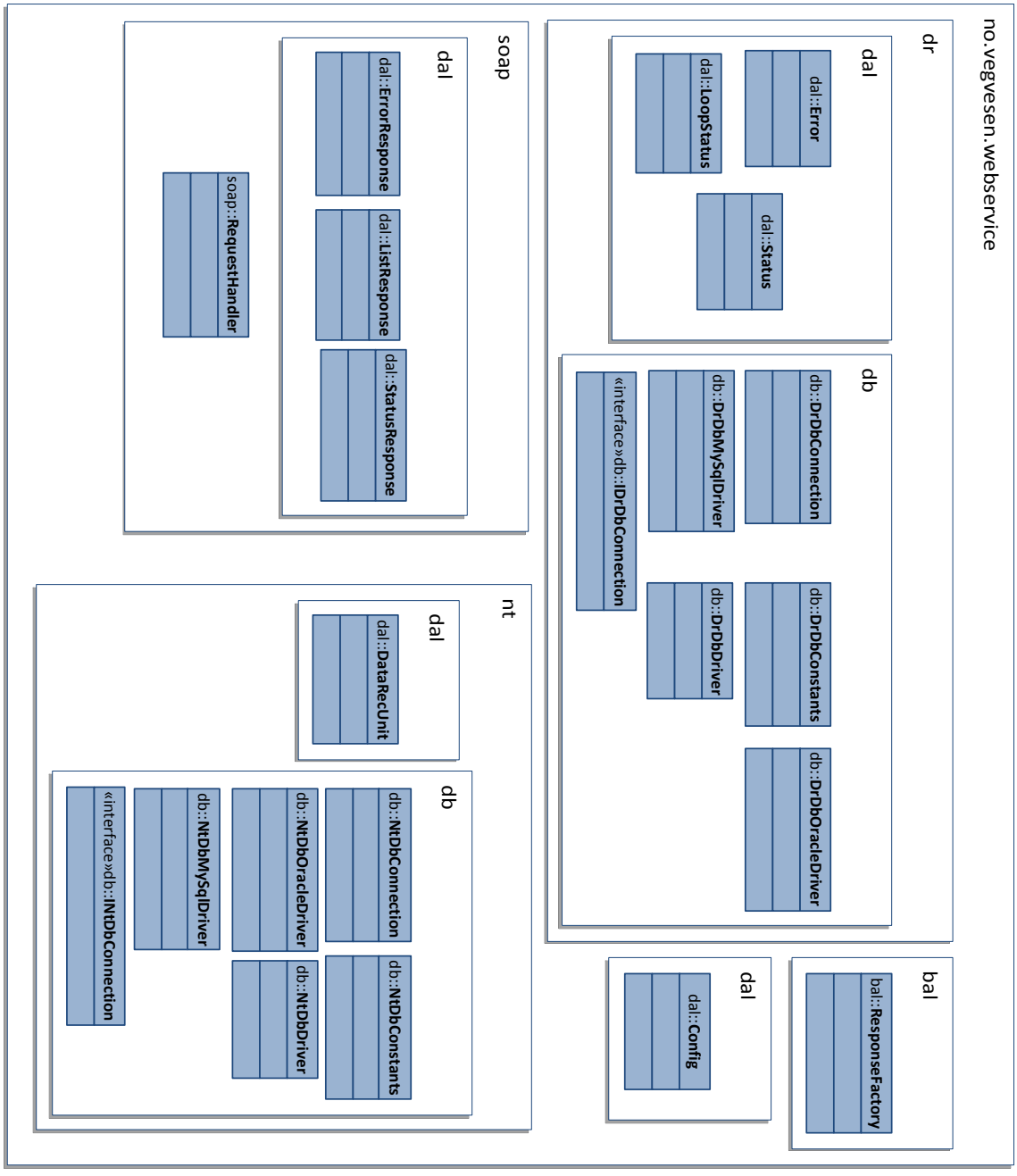

Figure D.3: Overview Class Diagram of the WebService

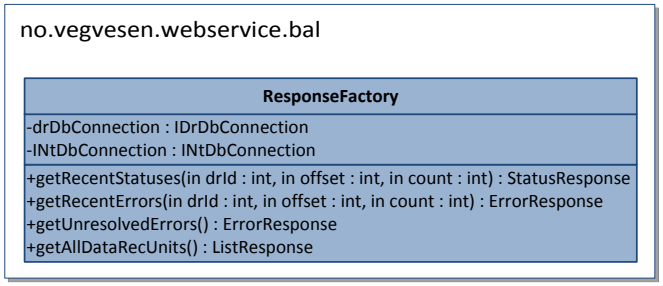
no.vegvesen.webservice.bal
ResponseFactory
-drDbConnection : IDrDbConnection
-INtDbConnection : INtDbConnection
+getRecentStatuses(in drId : int, in offset : int, in count : int) : StatusResponse
+getRecentErrors(in drId : int, in offset : int, in count : int) : ErrorResponse
+getUnresolvedErrors() : ErrorResponse
+getAllDataRecUnits() : ListResponse

Figure D.4: Class Diagram: no.vegvesen.webservice.bal

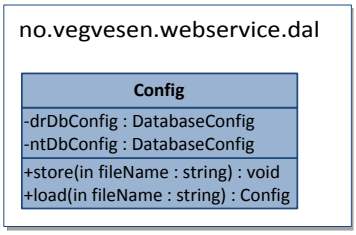

Figure D.5: Class Diagram: no.vegvesen.webservice.dal

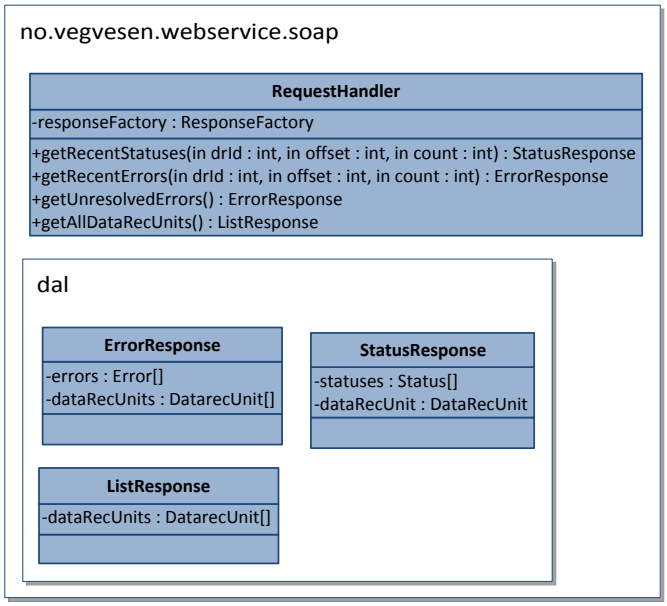

Figure D.6: Class Diagram: no.vegvesen.webservice.soap

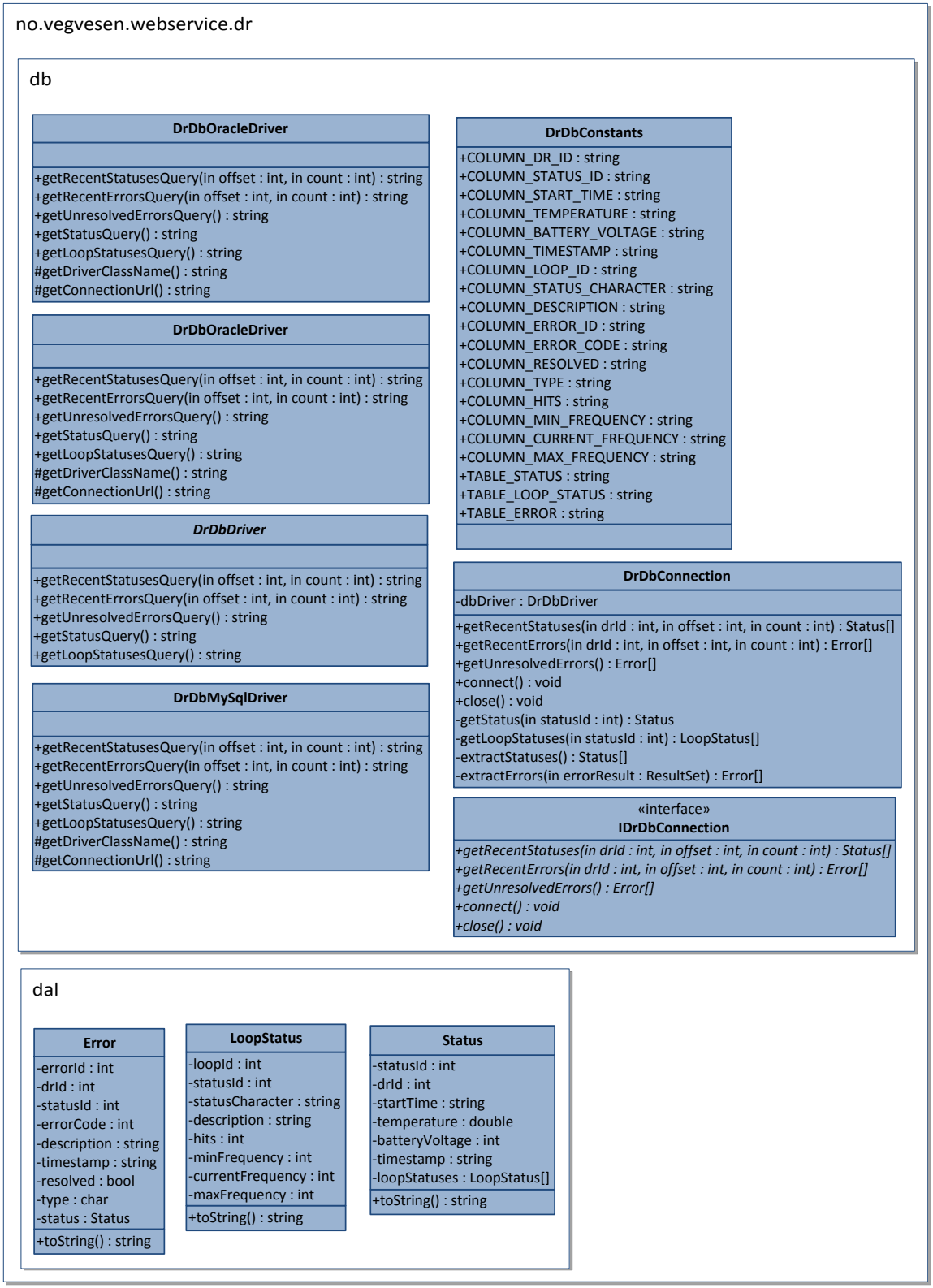

Figure D.7: Class Diagram: no.vegvesen.webservice.dr

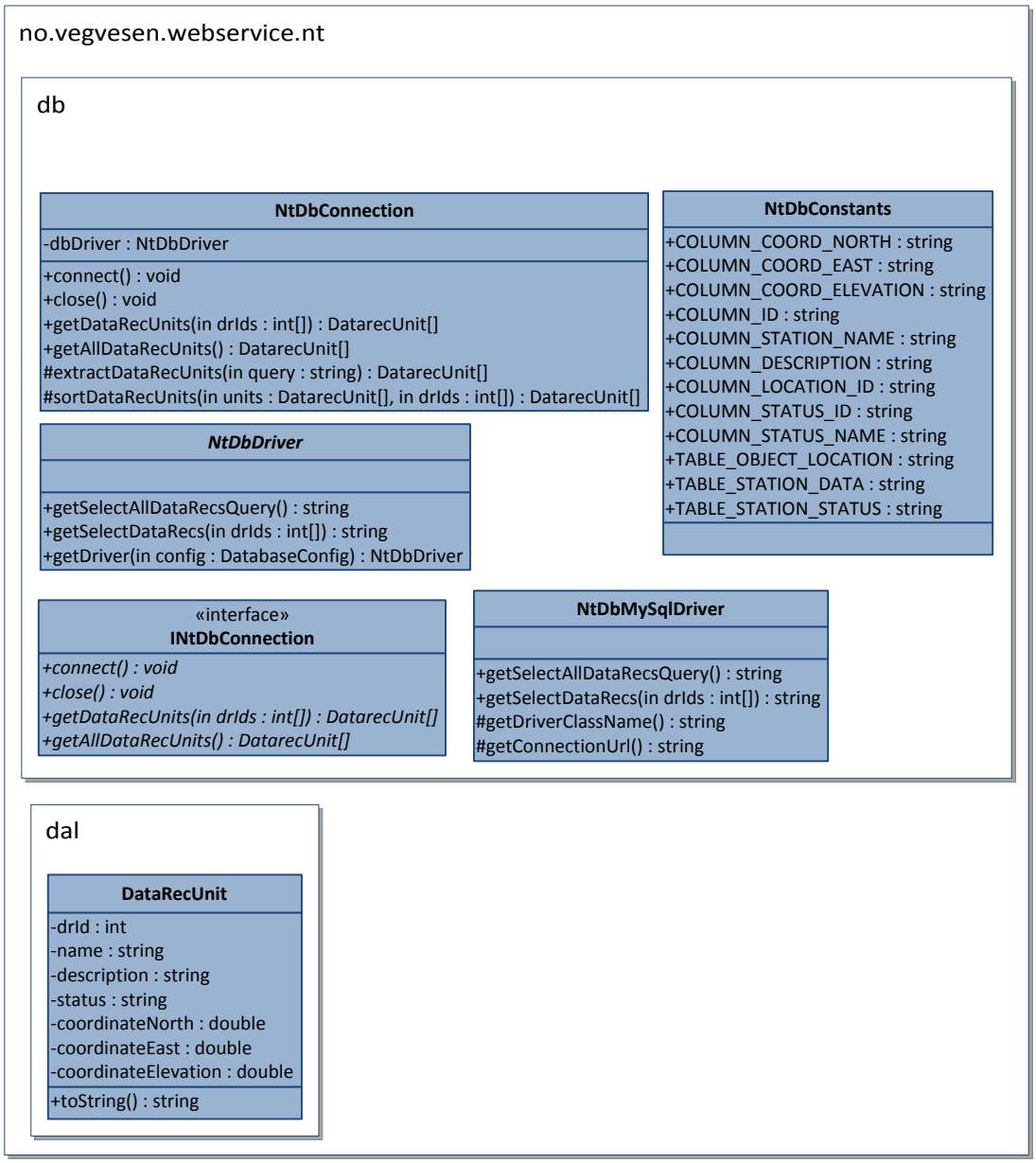

Figure D.8: Class Diagram: no.vegvesen.webservice.nt

D.4 Error Handler

In this section the design of the Error Handler is presented as ER and class diagrams. In order to save space the class diagrams does not contain getter and setter methods.

D.4.1 Initial Design

In this section the initial design of the Error Handler is presented. This design was modified after changes to the requirements.

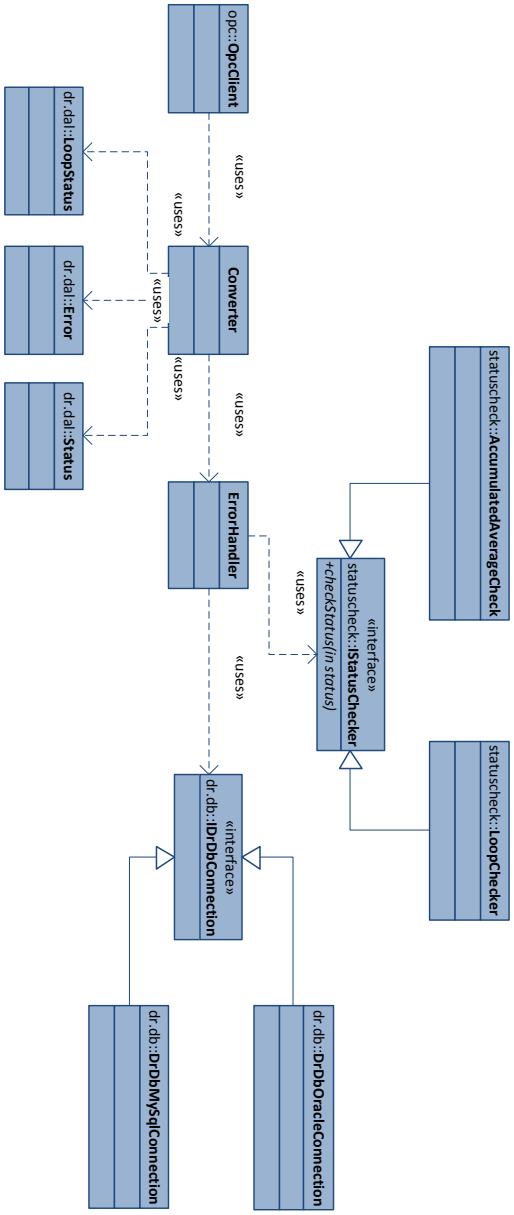

Figure D.9: Initial ER diagram of the Error Handler

D.4.2 Final Design

In this section the final design of the Error Handler and ErrorHandlerService is presented.

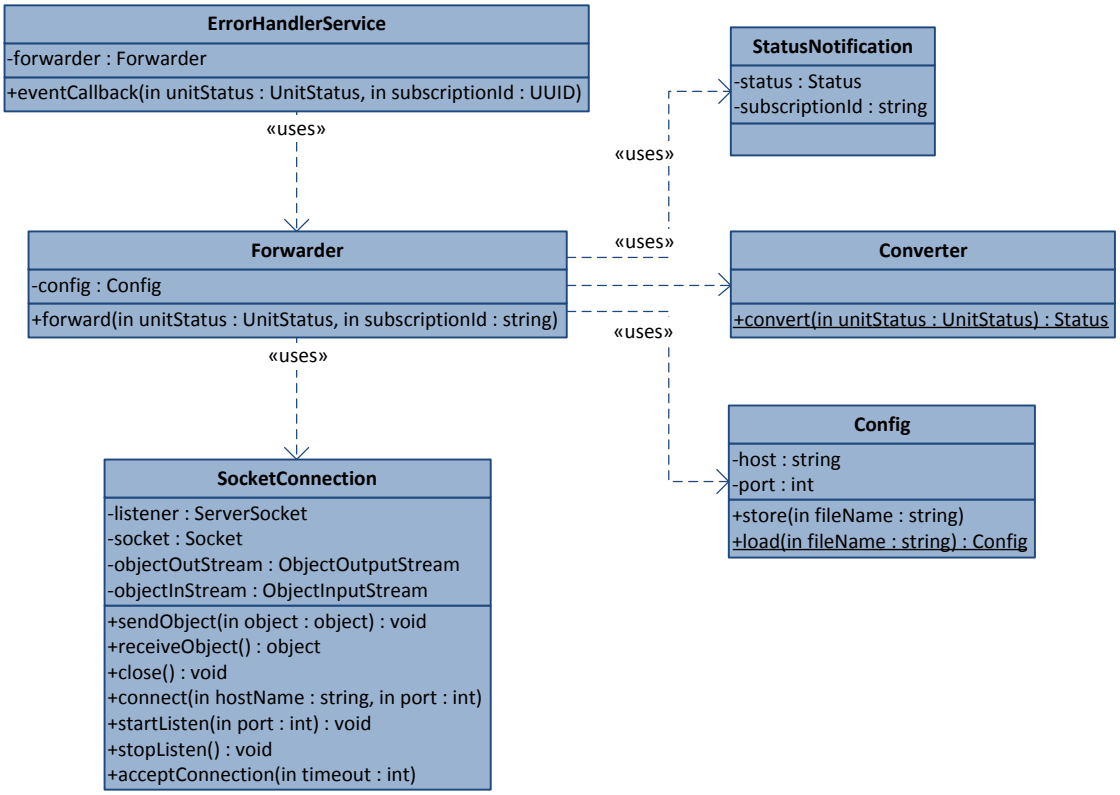

Figure D.10: ER Diagram of the ErrorHandlerService

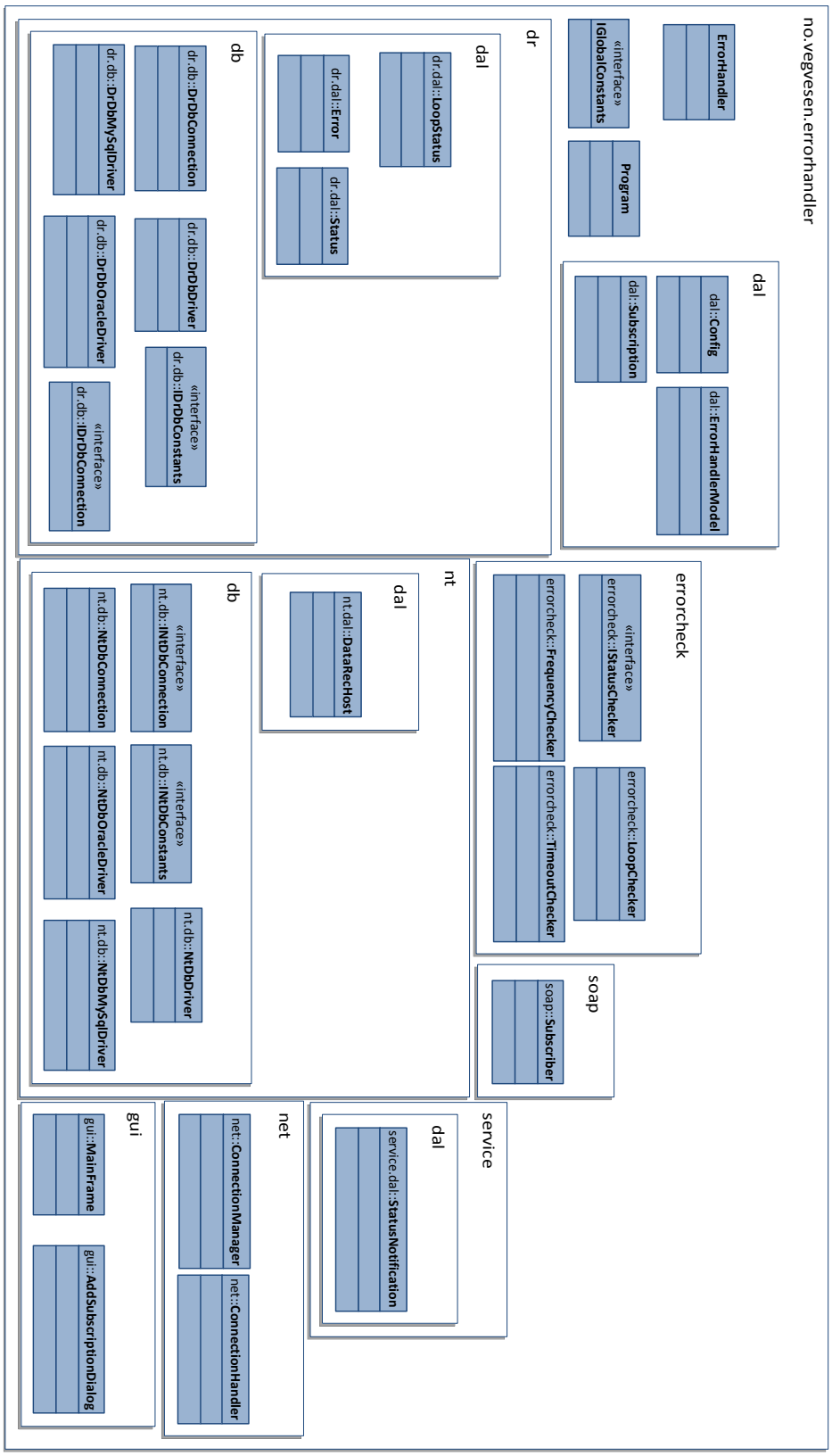

Figure D.11: Overview Class Diagram of the Error Handler

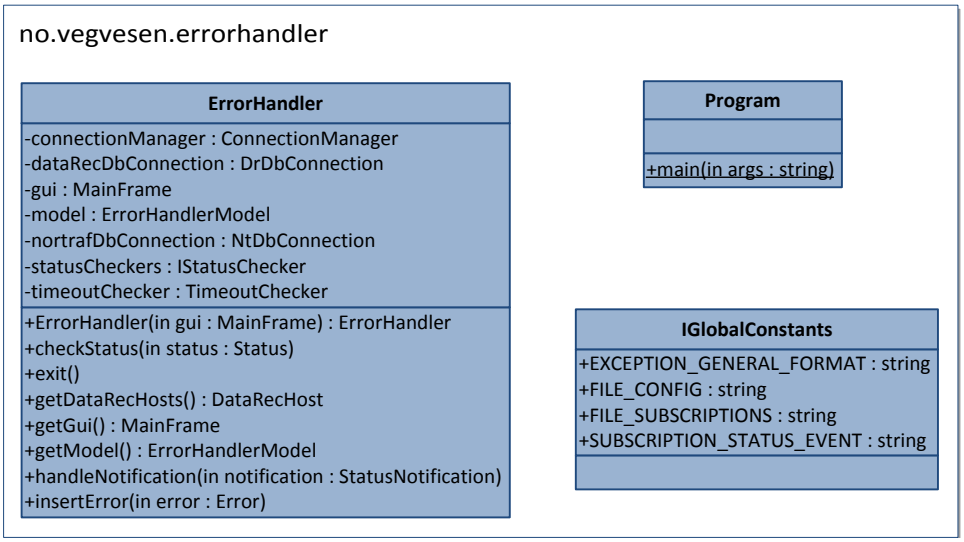

Figure D.12: Class Diagram: no.vegvesen.errorhandler

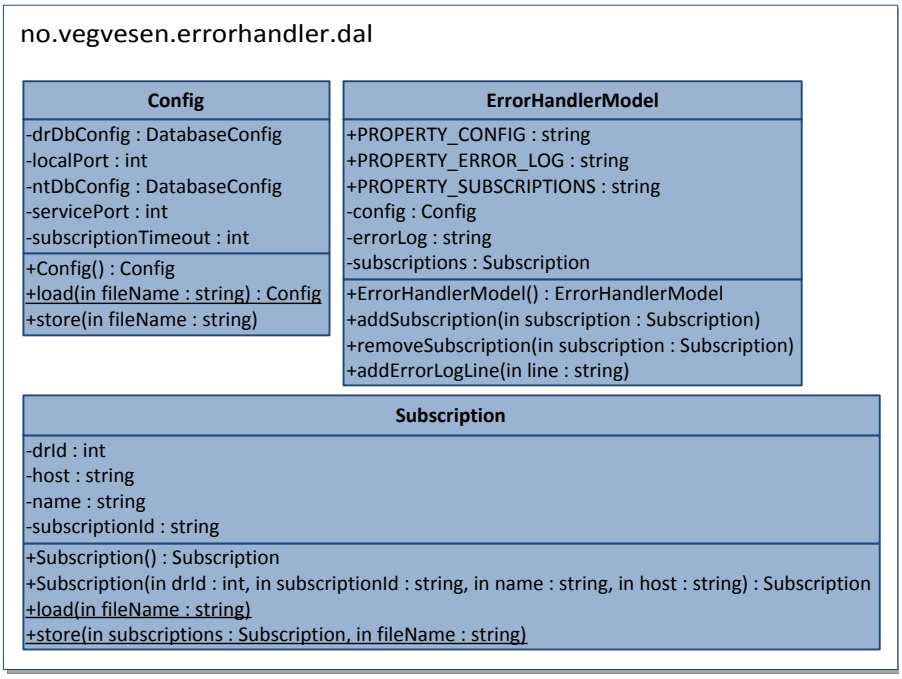

Figure D.13: Class Diagram: no.vegvesen.errorhandler.dal

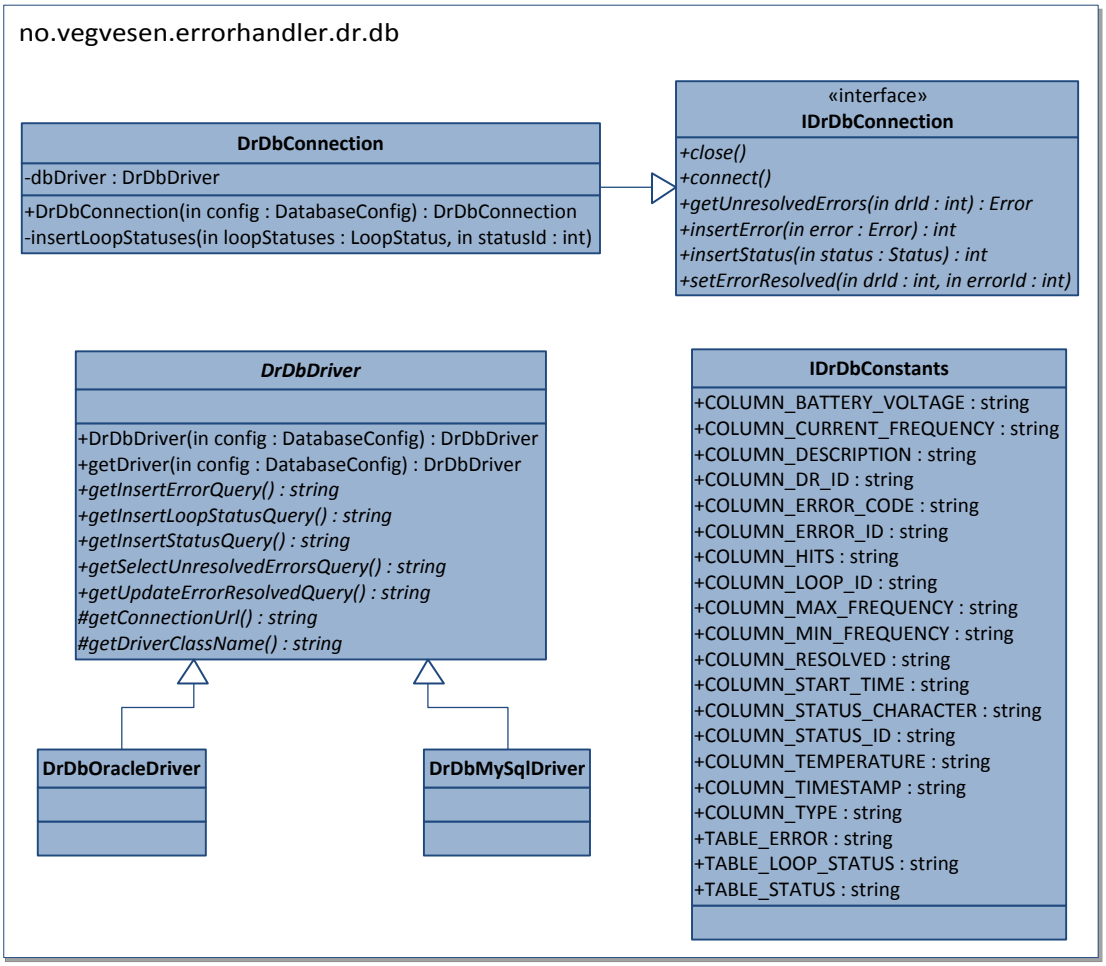

Figure D.14: Class Diagram: no.vegvesen.errorhandler.dr.db

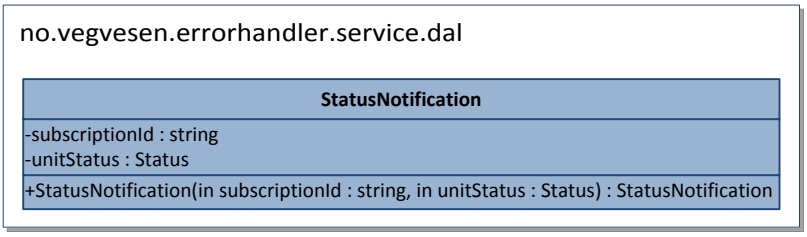

Figure D.15: Class Diagram: no.vegvesen.errorhandler.service.dal

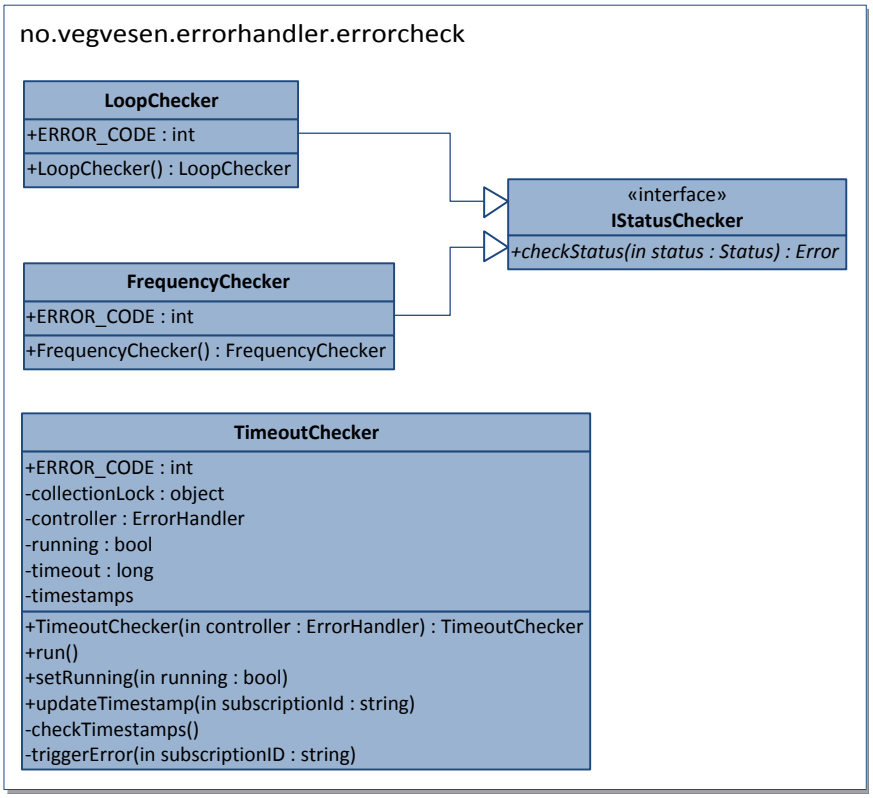

Figure D.16: Class Diagram: no.vegvesen.errorhandler.errorcheck

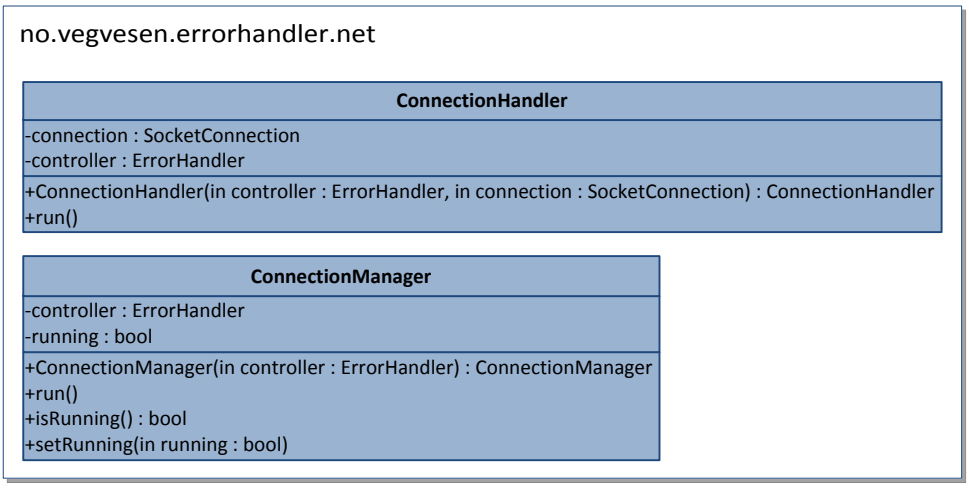

Figure D.17: Class Diagram: no.vegvesen.errorhandler.net

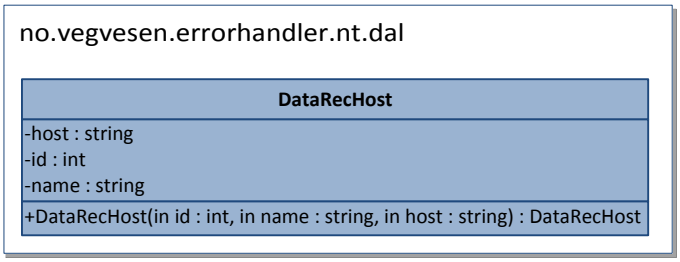
no.vegvesen.errorhandler.nt.dal
DataRecHost
-host : string
-id : int
-name : string
+DataRecHost(in id : int, in name : string, in host : string) : DataRecHost

Figure D.18: Class Diagram: no.vegvesen.errorhandler.nt.dal

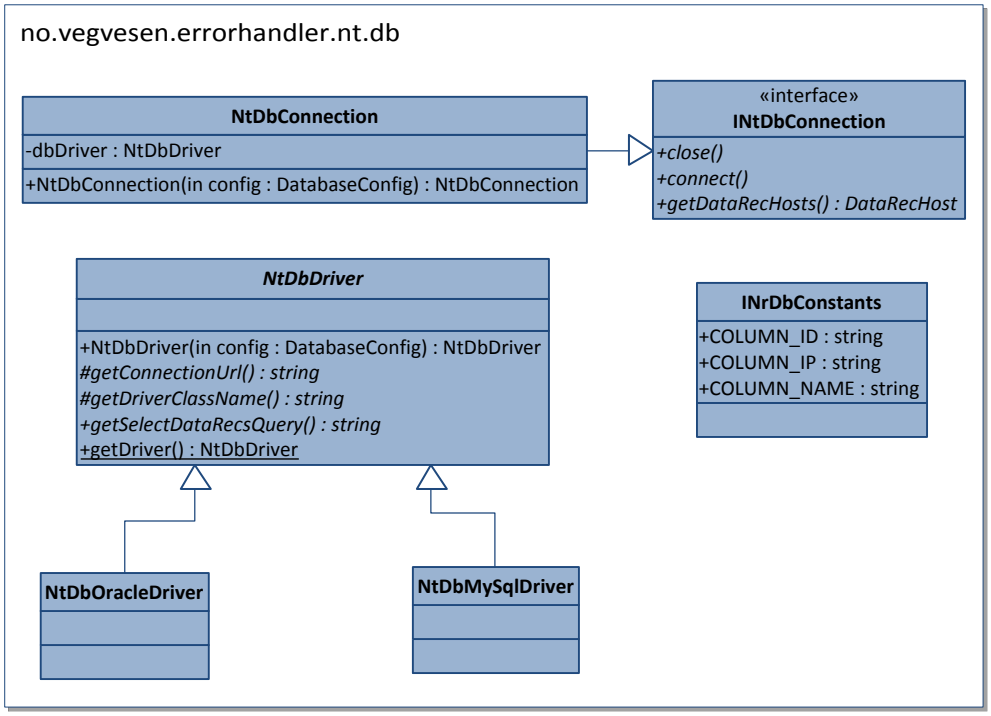

Figure D.19: Class Diagram: no.vegvesen.errorhandler.nt.db

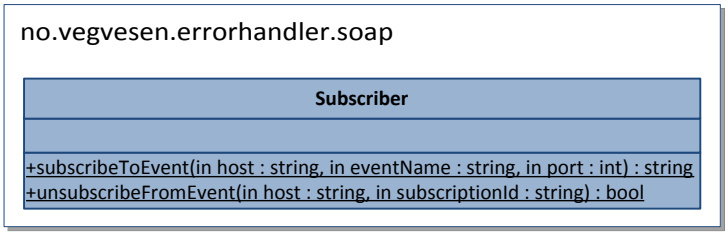
no.vegvesen.errorhandler.soap
Subscriber
+subscribeToEvent(in host : string, in eventName : string, in port : int) : string
+unsubscribeFromEvent(in host : string, in subscriptionId : string) : bool

Figure D.20: Class Diagram: no.vegvesen.errorhandler.soap

D.5 Database

In this section the database scheme is presented.

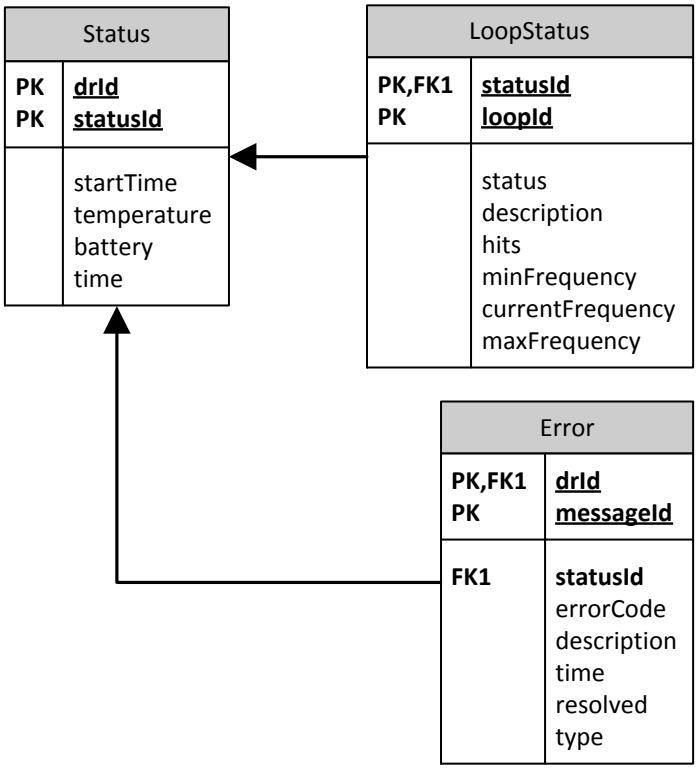

Figure D.21: Database Scheme of the Datarec Database

D.6 ONSITE server

In this section the design of the ONSITE Server is presented.

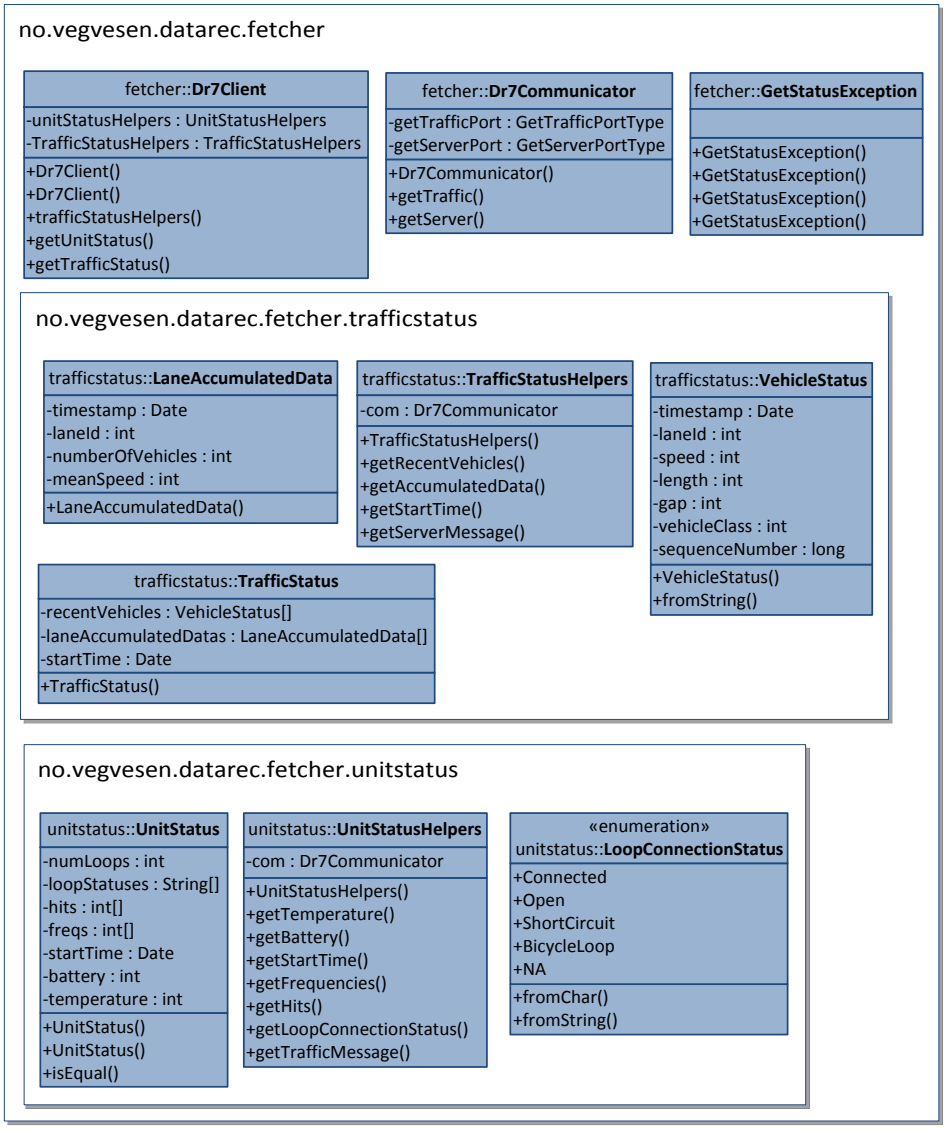

Figure D.22: Class Diagram of DrRegusterNotificationPusher

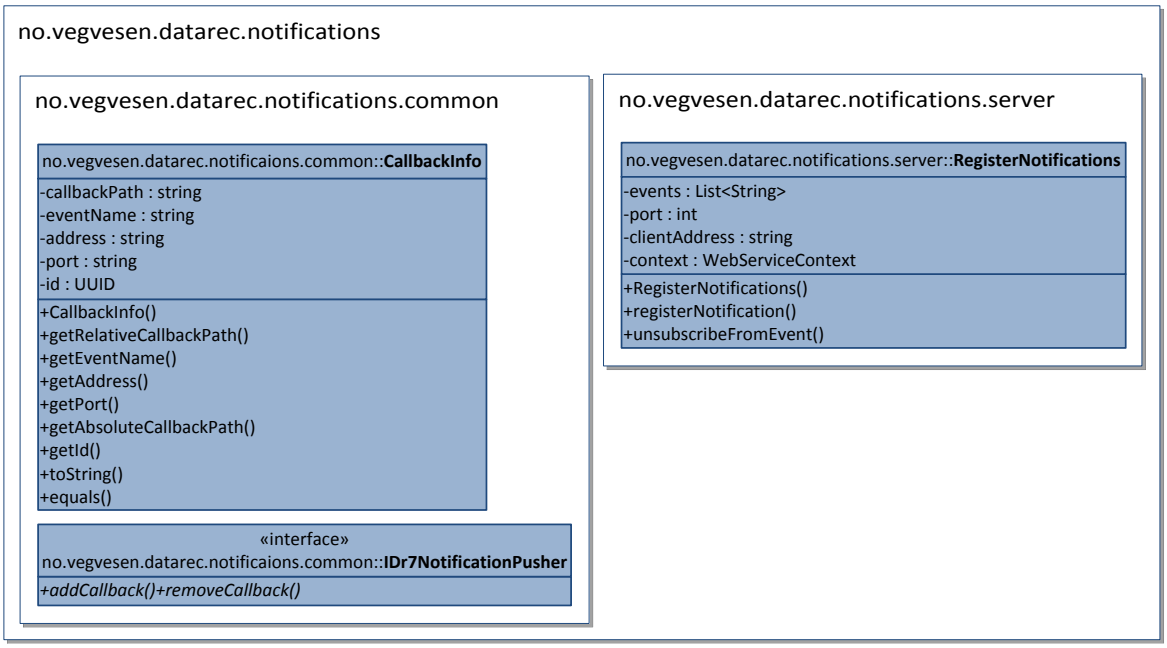

Figure D.23: Class Diagram of DrRegisterNotifications

E Appendix: Further Use of Traffic Data

Contents

The Norwegian Public Roads Administration is at some point going to make parts of the information that they gather public. This opens up for some new interesting ideas. Some of these ideas need cooperation with other markets and business brands.

Cafeterias, gas stations and hotels A future use of the information could be to notify roadside cafeterias, gas stations and hotels. If the counting of cars passing is somehow coupled with GPS technology, it could tell roadside service installations if they, statistically, would get new customers. This could be calculated from how long the vehicles have been driving and in which direction they are traveling.

Traffic Jam Assessment The information can also be used to assess if it is a traffic jam. If there is a traffic jam, information of this can be given to incoming vehicles through signs informing them that they might want to take another route to their destination. This could be for vehicles approaching on the same road and vehicles that are coming onto this road.

Police, Ambulance and Firefighters The data could be sent to the vehicles used by the police, ambulances and the firefighters. This information could then be used to calculate the most efficient route to their destination.

Lottery There could be created a *Vehicle Lottery*. The lottery could either be based on pure statistical use of the data, or with some kind of chip that is recognized as a "lottery chip" to grant the vehicle the ability to participate. This method could also be used to draw some people away from the more trafficated roads. A downside of this is that it might take concentration away from driving, and increase the probability of accidents.

Traffic Lights Real time traffic data could be used to control the traffic lights. With real time control of the traffic flow, the vehicle pollution in the bigger cities might be reduced.

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